The American Midland Naturalist

Devoted to Natural History, Primarily
that of the Prairie States

Founded by J. A. Nieuwland, C.S.C.

Contents

Ecological Studies on Selected Marine Intertidal Communities of Monterey Bay, California—*Willis G. Hewatt* 161

Further Studies on North American Gyrodactyloidea—*Justus F. Mueller* 207

Two New Blind Isopods from Northeastern Oklahoma—*H. D. Chase* and *A. P. Blair* 220

The Genera Cyperana and Paluda (Homoptera-Cicadellidae)—*Dwight M. DeLong* 225

New Moss-Mites, Chiefly Midwestern - II.—*Arthur Paul Jacot* 237

The Biology of Physa anatina Lea, a Snail Living in a Sewage Treatment Plant—*Thelma Fish Brown* 251

A Season with Holbrook's Chorus Frog (Pseudacris ornata)—*Francis Harper* 260

Observations on Bufo cognatus with Special Reference to the Breeding Habits and Eggs—*Arthur N. Bragg* 273

Ecological Observations on Amphibians and Reptiles Collected in Southeastern Oklahoma during the Summer of 1934—*Albert H. Trowbridge* 285

Notes and Discussion:
Mustela cicognanii, the Short Tailed Weasel, Incorrectly Ascribed to Ohio—*E. Raymond Hall* 304

Book Reviews 305

Vol. 18 MARCH, 1937 No. 2

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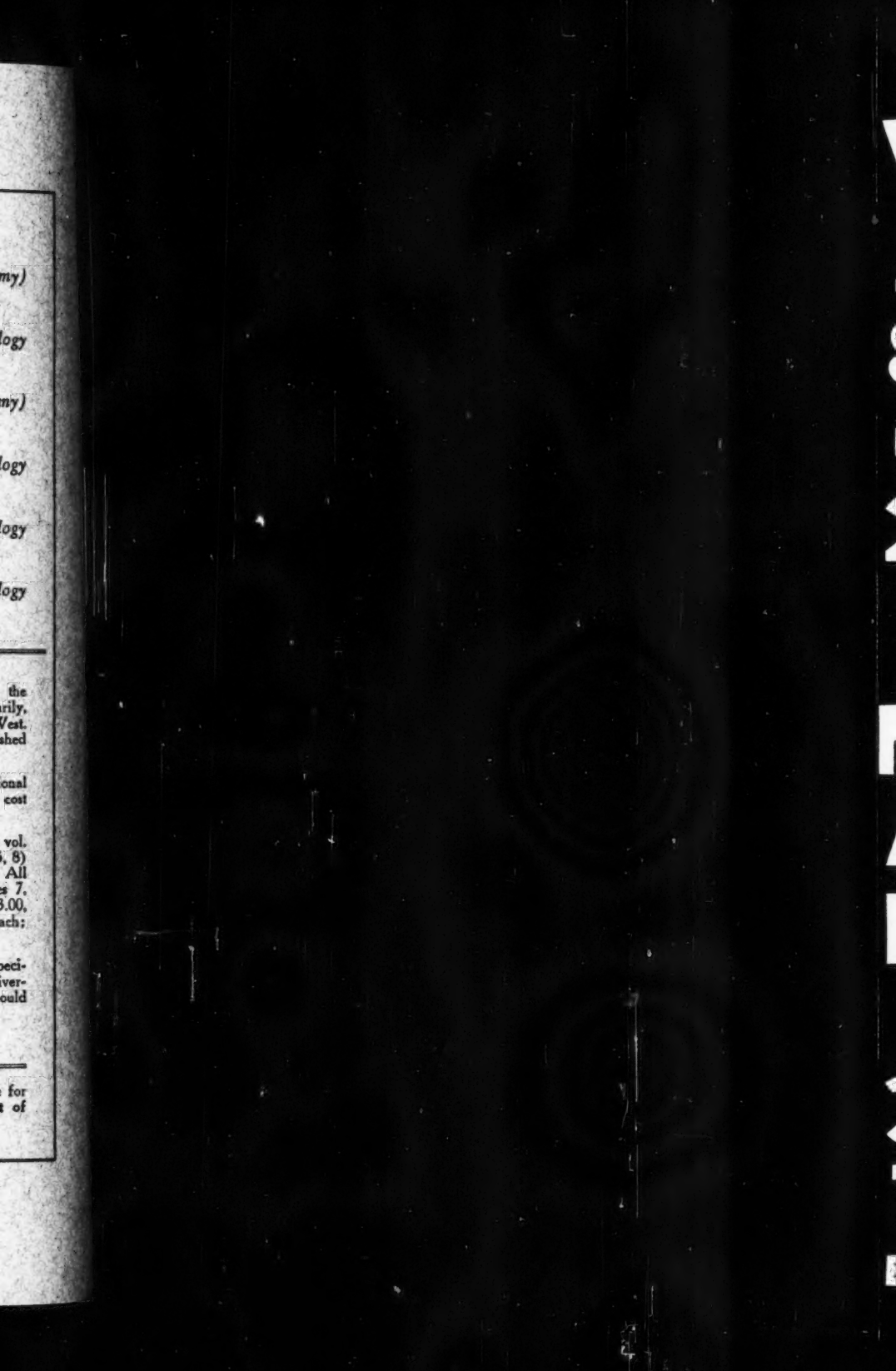

The American Midland Naturalist

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VOL. 18 MARCH, 1937 No. 2

Ecological Studies on Selected Marine Intertidal Communities of Monterey Bay, California*

Willis G. Hewatt

CONTENTS

Introduction ---- 161
I. Location of Investigated Area ---- 164
II. General Environmental Conditions ---- 166
1. Geological Features ---- 166
2. Temperature of the Water ---- 167
3. Salinity ---- 168
4. Phosphate and Silicate ---- 168
5. Air Temperature and Rainfall ---- 168
6. Aeration ---- 170
7. Light Conditions ---- 170
8. Tides ---- 170
III. Apparatus and Methods ---- 172
IV. Some Questions Concerning the Terminology of the Biotic Distribution and Zonation ---- 174
V. Animal Distribution and Zonation ---- 177
1. Supralittoral ---- 183
2. Littoral ---- 183
3. Seasonal Migrations ---- 189
VI. Food Relationships ---- 192
VII. Systematic List of Species ---- 199
Summary ---- 201
References ---- 202

Introduction

Marine sociological investigations have been carried out by various workers in several widely separated intertidal regions. Most of these studies are in the form of descriptive surveys, such as Verrill ('73), in the Vineyard Sound region; Sumner, *et. al.* ('11) and Allee ('23), in the Woods Hole vicinity; Hedley ('15) and Johnston ('17), on the Australian beaches; Shelford and Towler ('25), in the Puget Sound area of the Pacific coast; and Gislen ('31), in the Misaki district of Japan. Quantitative investigations in this field have been made on the Scottish coast, by Stephens ('28); in the Gullmar Fjord,

* This paper describes the results of part of the investigations carried out and submitted to the faculty of Stanford University as partial fulfillment of the requirement for the degree of Doctor of Philosophy.

Photograph of Cabrillo Point taken from the air.

by Gislen ('30) and Molander ('29); and on the coast of England, by Elmhirst ('32) and Pierrie ('32).

The results of these pioneer investigations have demonstrated the need of more extensive as well as intensive studies in other coastal rgions. By acquiring a detailed knowledge of the great variety of conditions represented in different littoral areas, more valid conclusions may possibly be drawn concerning the interrelationships of intertidal organisms and the effect of physico-chemical factors upon the restricted distribution of animal associations.

A survey of the literature published on the littoral faunas of the California coast reveals that, until the present time, practically all of the work has been of a taxonomic, morphological and embryological nature. The ecological aspect has been greatly neglected. It is true that scattered facts concerning the specific ecology of some of the animals are to be found in these papers and that the ecology of a few species has been dealt with in quite an exhaustive manner, but not a single paper dealing primarily with the sociological aspect of the littoral communities has been published.

The present paper is the result of a quantitative examination of the rocky beach faunas of the southern shore of Monterey Bay, California. The work was begun in October, 1931, and was carried on continually until June, 1933. Additional observations were made during the summer months of 1934.

The work was begun with the purpose of trying to determine more definitely the nature and causes of the vertical and horizontal zonation of the littoral invertebrates of a rocky shore. Notes on the prevailing physical and chemical conditions of the area were recorded throughout the period of investigation. In as many cases as the evidence permits, the effects of the physical factors upon the habits of the organisms are pointed out. The effects of some of the biotic factors upon the zonation were also studied and are recorded in this paper. Special attention was given to the feeding habits of the organisms.

The work is mainly concerned with 90 of the most commonly occurring macroscopic species of the intertidal area. A complete list of the species (170) identified during the course of the work is given at the end of the paper.

I wish to take this opportunity to express my appreciation to Professor Tage Skogsberg for many valuable criticisms and helpful suggestions offered in the course of this investigation.

Thanks are due Professor G. E. MacGinitie of the California Institute of Technology for having suggested the problem and for his untiring aid and sympathy in getting the project underway.

The work could not possibly have been carried out without adequate laboratory facilities and field equipment. For these and other courtesies I am indebted to Doctor W. K. Fisher, Director of Hopkins Marine Station.

In the study of an ecological problem, especially when dealing with marine communities where the relations of a great variety of species are concerned, one becomes indebted to a number of workers in special fields. The following taxonomists have very kindly aided in the determination of many of the organisms collected. Mrs. G. E. MacGinitie checked the identifications of all of the crustacea; Mrs. Ida Oldroyd, Curator of the Museum of Paleontology of Stanford University, assisted in the

Photograph of Cabrillo Point taken from the air.

determination of some of the gastropods; Doctor F. N. MacFarland identified most of the nudibranchs; Doctor R. L. Bolin aided in classification of the fishes.

Mr. H. W. Graham has very kindly given me certain photographs reproduced in this paper.

I.—Location of Investigated Area

The area studied in the present investigation is located on the southern margin of Monterey Bay, California, near the border line between the cities of Monterey and Pacific Grove. Here the granite base of the Monterey Peninsula projects out into the bay, forming the promontory called Cabrillo Point or Mussel Point, on which the Hopkins Marine Station of Stanford University is situated (Fig. 1). The area is about two miles east of Lighthouse Point which marks the southwestern extremity of the Bay, and is approximately in latitude 36° 37′ N. and longitude 121° 54′, Greenwich meridian.

The ecological transect which was chosen for this work extended across the intertidal zone directly north of the Jacques Loeb laboratory of the Hopkins

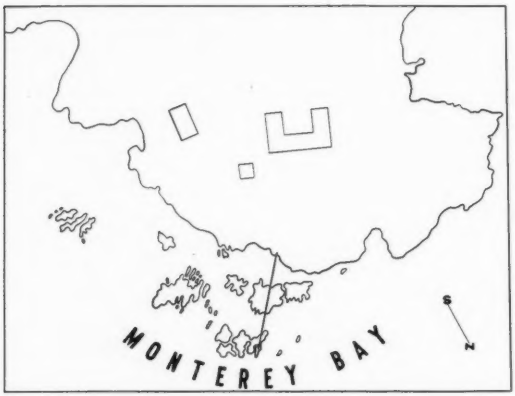


Fig. 1.

Map of Cabrillo Point. The line extending from the shore indicates the investigated ecological transect.

Marine Station and was 108 yards long and one yard wide, with a bearing of N. 38° E.

This region was selected, first, because of its nearness to the laboratories of the marine station and, second, because the nature of the shore at this point allows several characteristic types of animal habitats to be exposed between the limits of the tides. By choosing this area, located near the laboratories, it was convenient to study the fauna throughout the entire year and to observe the seasonal changes in the inhabitants. Continuous and close observation was obviously one of the primary considerations in the investigation.

At Cabrillo Point a number of outlying, small granite islands project permanently above the sea level (Fig. 2). They protect the innermost portion

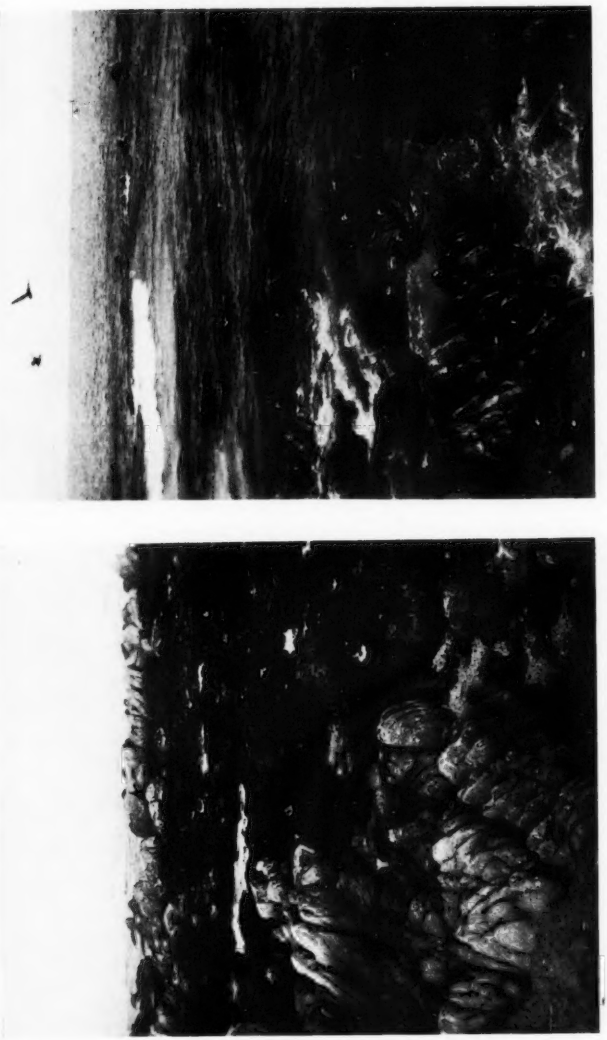


Fig. 2. A. View of the investigated area, taken from the shore during a period of low tide. B. View from the same location, taken during a period of high tide.

of the selected area from the intense wave action, characteristic of this region, while the outermost part of the line is exposed to the full force of the surf. Thus protected and exposed biotic associations occur within the tidal range.

The middle part of the selected strip crosses a fairly large tidepool which is covered with water even during the lowest range of the tides (Fig. 3). The strip also crosses two shallow channels between squares 41 and 48, and 85 and 90 (see p. 174). There is a repetition of low-tide level faunas on either side of these channels.

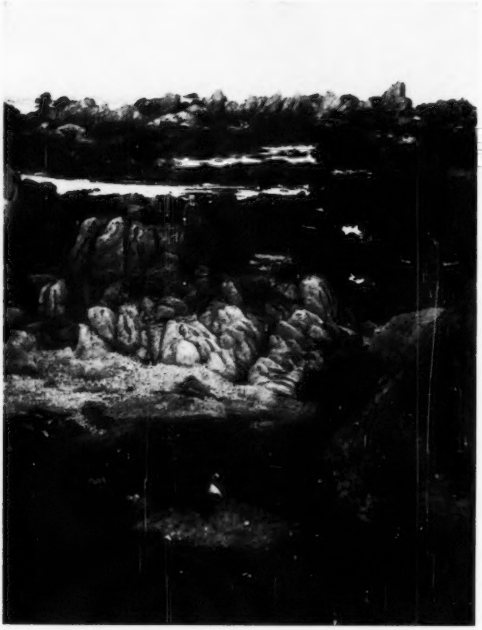


Fig. 3. Tidepool, in the background, across which the ecological transect passes.

It may finally be noted that the systematic study of the organisms of this locality has reached a state of perfection which allows an accurate determination of the material, a feature of paramount importance to the ecologist.

II.—General Environenmental Conditions

1. Geological Features

The substratum of the rocky shore at Cabrillo Point is a portion of the granite porphyry which forms the core of the Monterey Peninsula. According to Galliher ('32, p. 51), this porphyry is a local phase of the quartz-diorite which is of pre-Cretaceous age. The massive granite is cut by numerous pegmatite dikes. The removal of the granite, by weathering, from between

the more resistant dikes produces a very rugged rock surface. The shore is also characterized by many large, granite boulders and by rocky islands which project above the water level near shore.

These features offer a very large surface for the attachment of sessile organisms and also present the varied animal habitats characteristic of a rocky coast.

2. Temperature of the Water

Daily temperature and salinity readings for the surface waters of Cabrillo Point are kept by the Scripps Institution of Oceanography, La Jolla, California. The data concerning these factors were very kindly placed at my disposal by Doctor E. G. Moberg, Acting Director of the Scripps Institution.

Figure 4 shows the records of the weekly mean and extreme temperatures of the surface water during the year 1932, in which period the greater part of this investigation was carried out. The weekly mean temperatures for a period of nine years are also given in this figure (see also Bigelow and Leslie, '28, p. 447).

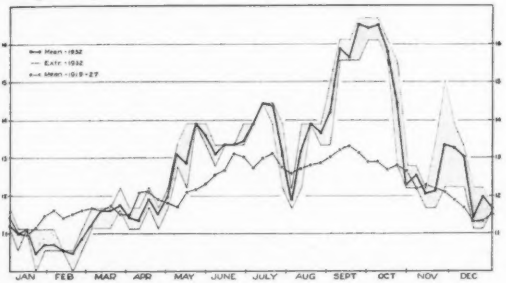


Fig. 4. Graph showing the temperature of the surface waters at Cabrillo Point.

It is evident from this graph that the temperature of the surface water at Cabrillo Point is characterized by two important features: first, the average temperature is moderately low to intermediate; and, second, the amplitude of variation is comparatively narrow. The lowest temperature, recorded in January and February, was as high at 10° C. The highest temperature, 16.8°, was reached in the latter part of September.

The figure shows that the highest temperatures occur regularly in the early fall. The mean weekly temperatures recorded over a long period of time range through approximately 2.5° C., a strikingly narrow amplitude.

A number of temperature readings were made at different hours of the day during all seasons in order to determine the variations throughout the day. These records demonstrate that the thermal variation is slight. The highest temperature recorded in this manner was 17.3°, on July 1, 1932, at 4 P.M. However, tidepool temperatures were recorded as high as 26° C. during July and as low as 3° C. during a severaly cold period in the winter of 1932.

The fact that the prevailing temperatures are fairly low to intermediate gives to the fauna of the area a comparatively northern aspect.

3. Salinity

There is practically no permanent fresh water drainage along the southern margin of Monterey Bay. The greatest fresh water supply of the Bay comes from the small Salinas River which enters the bay at a distance of approximately 20 miles northeast of Pacific Grove.

The daily salinity records for 1932 show a variation in salt concentration between 32.12 and 33.821 grams per liter. In this respect, too, the investigated area exhibits a very remarkable uniformity.

During the winter, when the rainy season occurs, the tidepools are greatly diluted. They often contain practically fresh water for short periods of time. Hardly any rain falls in this region from June to October 1, inclusive, and during the larger part of this period the drainage from the Salinas River is, for all practical purposes, negligible.

Figure 5 shows the weekly mean and extreme salinities for 1932 and the weekly means for the years 1919-1927, inclusive, according to the determinations made by Scripps Institution of Oceanography, ('28, p. 453).

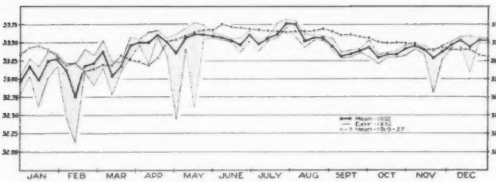


Fig. 5. Graph showing the salinities of the surface waters at Cabrillo Point.

4. Phosphate and Silicate

Weekly readings of the phosphate ($P0_4$) and silicate ($Si0_2$) of the surface waters near the laboratories were made during a full year, beginning in June, 1932. The results of these analyses are shown in Table 1. They demonstrate the presence of a perennial supply of these compounds sufficient for the development of the rich planktonic flora characteristic of this region.

Table 1. Average Monthly Phosphate and Silicate (g. per L.)

Month	Phosphate	Silicate
June 1932	0.05818	1.0628
July, 1932	0.04776	0.8502
Aug., 1932	0.06060	1.0246
Sept., 1932	0.07071	0.6148
Oct., 1932	0.08280	0.8880
Nov., 1932	0.06734	0.6148
Dec., 1932	0.10657	0.8198
Jan., 1933	0.10704	0.8289
Feb., 1933	0.12310	0.6660
Mar., 1933	0.11487	0.5911
Apr., 1933	0.10122	0.7515
May, 1933	0.12323	0.8485

5. Air Temperature and Rainfall

No continuous records of the air temperature and precipitation are kept at the Hopkins Marine Station. These conditions, however, are recorded at

a meteorological station which is maintained on the Monterey Peninsula by the U. S. Weather Bureau at the Del Monte Properties Company. Some of the data collected by this organization were kindly placed at my disposal by Mr. L. W. Perry, director of the Del Monte Station.

TABLE 2. Air Temperatures for 1932

	Max.	Min.	Mean.	Mean Max.	Mean Min.	Av.Daily Range
January	68°	30°	45.5°	55.5°	36.0°	19.0°
February	77	28	47.2	57.6	36.7	20.9
March	78	31	56.1	62.4	40.8	21.6
April	79	33	53.0	64.0	42.0	22.0
May	84	43	57.2	65.4	48.9	16.5
June	80	42	58.9	67.5	50.3	17.2
July	78	46	59.7	68.6	51.0	17.5
August	80	43	60.3	69.7	50.9	18.8
September	67	48	61.7	71.1	62.3	18.3
October	80	37	66.5	67.4	45.5	21.9
November	81	32	62.3	65.0	40.7	24.3
December	66	34	43.2	53.7	32.7	21.0

Table 2 demonstrates that the coldest temperatures prevail during the months of December, January and February. The minimum temperature recorded for 1932 was 24° F. (-4.4° C.). Such low readings, however, are extremely rare for the coastal area of the Monterey Peninsula. The highest temperatures were reached during the month of September. The average daily range for 1932 was 20° F. (11.1° C.).

From the viewpoint of ecology, the most important information to be derived from these data is that the animal and plant communities, when exposed by the tide, very seldom are subjected to freezing air temperatures. It is, indeed, very doubtful if exposure to cold air ever inflicts any serious damage to the fore-shores of this region. Other facts noteworthy in this connection are that during the warmer parts of the year foggy weather is very common and tidal exposure, generally speaking, occurs at night and in the early morning when the air temperatures still are comparatively low.

The average amount of rainfall in this area is very low as shown in Table 3.

TABLE 3. Precipitation for 1932

	Total Moisture	Greatest Daily	No. of Days .01"
January	4.06"	1.53"	15
February	3.07	1.17	10
March	0.33	0.24	3
April	0.39	0.22	5
May	0.72	0.55	5
June	0.00	0.00	0
July	0.00	0.00	0
August	0.01	0.01	1
September	0.00	0.00	0
October	0.00	0.00	0
November	0.18	0.18	2
December	0.56	0.56	12

Total precipitation—11.16"

6. Aeration

No records of the oxygen content of the waters of Cabrillo Point were taken during the course of this work. It may be safely assumed, however, that the intertidal water is almost continuously saturated with oxygen because of the vigorous surf action in the area. Moreover, the abundant growth of algae found on the littoral rocks also aids substantially in keeping the oxygen content high.

The photograph shown in Figure 6 gives evidence of the intensive action of the surf in this region.

Fig. 6. View showing the heavy surf on the rocks at Cabrillo Point.

7. Light Conditions

A record of the overhead conditions in the vicinity of the area investigated was taken twice daily during the year 1932. The light conditions were recorded at 8 A.M. and at 1 P.M. The records show that the region is protected from direct insolation during most of the forenoons and late afternoons. There were often a few hours of intervening sunlight during the middle of the day. The summer months were found to be exceptionally foggy.

These weather conditions, of course, prevent a wide variation in the air temperature and thereby greatly enhance the productivity of life in the intertidal communities.

8. Tides

In Monterey Bay there are two high tides and two low tides in every lunar day of approximately 24 hours and 50 minutes. It is apparent, there-

fore, that on each succeeding solar day the corresponding tides occur 50 minutes later than on the previous day. The heights of the two daily tides are comparatively equal only during the half-moon periods. At the full and new moon periods there is a great difference between the levels of the tides, especially in the case of the low tides, due to the varying declination of the moon. During these periods there are very pronounced higher high and lower low tides with intervening lower high and higher low tides. For instance, on June 14, 1932, there was a difference of 2.5 feet between the two high tides, and on the 18th of the same month there was a difference of 4.8 feet between the two low tides. From such conditions, it follows that there is a wide range in the extremes of the tides but the mean range is much less in extent. For the year 1932, during which the greater part of this investigation was made, the extreme range of the tide was 8.6 feet while the mean range for the same period was 3.5 feet.*

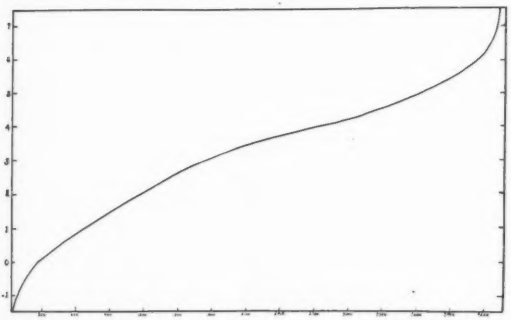


Fig. 7. Graph showing the number of hours of exposure at various levels in the intertidal during a period of six months.

This variation in the two daily tides has a pronounced effect upon the animal and plant communities of the intertidal belt. The organisms living near the high tide limit are exposed for longer periods of time than similarly located forms in regions where the tides are approximately equal. Conversely, the organisms at or near the low tide limit are exposed less frequently and for shorter total time. This condition or variation in the periods of exposure at different depths causes definite breaks in the biotic sequence of the intertidal area which will be discussed later in this paper.

E. F. Rickets (unpublished manuscript) has constructed a diagram to show the time of exposure of organisms at different levels in the intertidal belt. His data were taken from the records of the tide recording machine at Crissy Wharf, just inside the Golden Gate at San Francisco, for the six month period from January 1, to July 1, 1931. He calculated the number of hours of exposure at each six inch level and thus obtained the total for the six month period. By his kind permission, the results are shown in Figure 7.

* These figures were calculated from data given by the Coast and Geodetic Survey in the "Pacific Tide Tables" for the Golden Gate at San Francisco, which is the port of reference for Monterey.

A study of this graph reveals the fact that the organisms below mean lower low water (the 0.0 of the tide tables) are exposed for relatively short periods of time. At the mean high water level there is a definite upward bend of the exposure curve. Organisms above this level are exposed for relatively long periods of time.

It is a fact of the most profound ecological significance that at the levels noted in the last paragraph, there are also breaks in the sequence of the biotic communities. Below the mean lower low water line, one finds associations which extend below the littoral into the sublittoral. The area above the 5 foot level is inhabited exclusively by such forms as, for example, *Littorina planaxis* which can withstand long periods of exposure.

A further discussion of the effect of the tidal rhythms upon the vertical distribution of the littoral organisms is given in Part V.

III.—Apparatus and Methods

For the benefit of those who, without previous experience, intend to enter upon this type of work, it may be advisable to present in this connection a list and brief description of the apparatus and other materials which were found useful or indispensable in the course of this investigation.

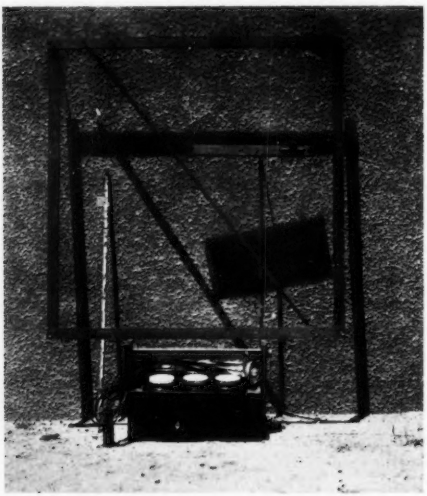


Fig. 8. Photograph of the field equipment used during this investigation.

The apparatus and materials were of three main types and may be listed as follows.

Field equipment: Square wooden frame of 1 square yard inside area; levelling instrument; stadia rod; iron rod, 3 feet long; thermometer; insulated wire line, 24 feet long; writing pad consisting of 20 white celluloid sheets, 8 x 4 inches.

Laboratory equipment: Aquaria; sorting pans; killing pans; glass tubing; preserving containers; finger bowls; syracuse dishes.

Chemicals: Formalin and ethyl alcohol, used as preservatives; magnesium sulphate, menthol, and chlorotone crystals, used as anaesthetics; Bouin's solution, used as a fixative.

The wooden frame, which was used to set off each square yard under analysis, was constructed of strips of hardwood (Fig. 8). Both sides of the frame were marked at one foot and 0.1 feet intervals in order that counts could be made and locations determined more accurately.

The instrument used in determining the levels along the ecological transect was constructed from angle brass. A piece of angle brass, 1.5 inches wide on each side and 17 inches long, was attached to the end of a brass tube, 20 inches long. A spirit tube of a level or "bubble" was fastened near one end of the angle brass and against the vertical portion. Above the bubble was placed a 1.0 x 1.5 inch mirror at an angle of 45° to the base. Small brass angles, each containing a 1/16 inch sight hole, were fastened at either end of the base at levels which caused a line connecting the sight holes to lie just above the level of the bubble. A brass rod, 20 inches long, was inserted into the bottom of the brass tube and was held in place by a brass sleeve containing a set-screw (Fig. 9). This simple apparatus can be made very cheaply and serves as well as a more expensive leveling instrument.

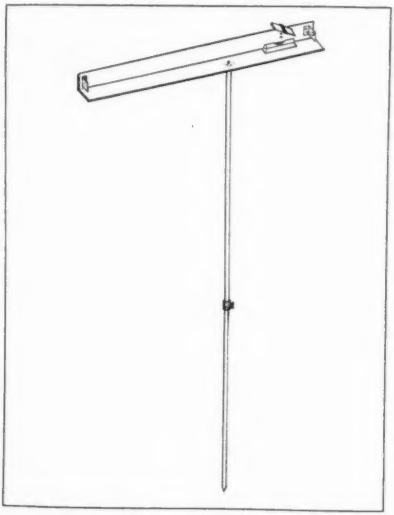


Fig. 9.
Diagram of
leveling instrument.

The collecting box was furnished with eight compartments, each large enough to hold one quart jar. Four holes for holding small vials, each 1 inch in diameter, were bored in the top of each end piece.

The small plankton net was used at various times for collecting the eggs and larvae. It was also useful in collecting small motile animals, e.g., isopods, amphipods, heteronereis, etc.

Several salt-water aquaria were used for observing the habits of various organisms.

Round pans, 12 inches in diameter, were used for sorting pans; and square pans, 12 x 12 inches, were employed for killing. Such an arrangement prevented the unintentional use of vessels which had contained a lethal substance.

The use of the remainder of the apparatus and chemicals will be explained in the following description of the methods used in the investigation.

In 1930, with the cooperation of the United States Coast and Geodetic Survey, Professor G. E. MacGinitie established four bench marks at intervals along a straight line, perpendicular to the shore, across the entire intertidal area directly north of the Jaques Loeb Laboratory of the Hopkins Marine Station. The first bench mark, at a level of 18.38 feet, was imbedded in a granite base upon the shore. The second one was fixed about 25 yards out in the intertidal area, at a level of 3.82 feet. The third point was set in the granite base of a fairly large tide pool about one half the distance across the intertidal zone, at the 1.67 foot level. The last datum point was located in the mussel habitat near the low tide level, at 0.3 feet.

The early part of the investigation included a survey of this area, a topographic sketch being made of each square yard. A record was kept of the number of individuals of each species found within the square yard units. With the exception of the upper 25 square yards, this field work could be done only at low tide periods during which times most of the area was exposed for three to four hours.

An iron rod, 3 feet long, was inserted in a small hole in the first bench mark and a stadia rod, 10 feet high, was set up with the base resting on the second bench mark and thus in line with the first and fourth datum points. Three guy ropes, with an iron weight attached to each loose end, were used to hold the stadia rod in an upright position. An insulated wire, 24 feet in length, was stretched along the line to be investigated. Starting from the second datum point, a wooden frame one yard square, was placed serially along the west side of the line and the organisms within each square area were counted and recorded. A surface view of each unit was also sketched. This procedure was repeated until a strip 108 yards in length had been mapped and a census taken of its animals.

The records were made on white celluloid sheets which were not destroyed when handled with wet hands and after becoming moistened by wave splashes. The sketches were transferred to a long roll of graph paper with one square inch representing the actual square foot.

The levels of each square were recorded. The leveling instrument described above proved to be a very effective means of determining the heights of the various points above sea level. From the data thus collected a vertical section was constructed on the graph paper just above the topographic sketches of the squares. Those sketches and sections, reduced to one inch to the square yard, are appended at the end of this paper.

After the qualitative and quantitative survey had been completed for the entire 108 square yards, it was realized that an intensive survey could not possibly be made over this large area during each season through the period in which the investigation was to be completed. A study of the data, however, revealed that certain squares could be set aside as typical of a section of the transect. These typical squares were re-examined intermittently during the changing seasons and the new populations were recorded. The variations in the numbers of the different organisms are discussed in the section on Animal Distribution and Zonation.

During the course of the survey, representatives of each species were collected and brought into the laboratory to be determined and preserved. Others were placed in aquaria equipped with running sea water where their habits could be more easily observed.

IV.—Some Questions Concerning the Terminology of the Biotic Distribution and Zonation

There exists in the ecological literature, particularly in that dealing with marine communities, a great deal of confusion and inconsistency concerning the definition and application of the terms pertaining to the distribution and zonation of organisms. Such a condition is not surprising when one considers

the small amount of quantitative investigation that has been done in marine sociology. It should also be kept in mind that the attempts to classify marine communities were made by workers in widely separated parts of the earth where the physical conditions, as well as the living forms, of the areas studied were far from similar. The gradual increase of knowledge of marine biotic communities has proven the futility of a general ecological classification based upon investigation in a few small areas.

Gislen (1930, pp. 46-62) presents an excellent account of the early history of the terminology used in the classification of the broader vertical regions of the sea. He calls attention to the fact that the attempts by the early investigators to classify the larger divisions of the sea floor upon the basis of biotic limits are of little value outside of the local areas. The different physical conditions which prevail in the various coastal regions may cause pronounced changes in the biotic levels. The organisms used in limiting the vertical zones may not even be present in some areas.

The littoral, with which we are concerned in the present work, has been defined in a number of ways by various investigators.

Some authors extended the lower limit of the littoral far below the intertidal area. For examples note the works of Peterson ('13), Murray and Hjort ('12), and Russell and Yonge ('23).

Most of the more recent writers limit the littoral to the intertidal area, but still there appears to be no agreement in regard to the definite limits.

Following the detailed definition of the littoral given by Gislen ('30, p. 48), the fundamental limits of the littoral are: *the mean higher high water line of spring tides and the mean lower low of spring tides*. It appears to me that this definition of the limits is justifiable, although, as pointed out by Gislen, the exact limits may be altered in certain regions by local physical conditions.

Those forms which inhabit the belt three or four feet above the high tide limit, and at the same time are definitely halobiotic, are referred to the supralittoral. This area is also inhabited by lizards and a few species of insects and arachnids. These are not taken into account in this work.

In the littoral region, where the physical and biological environments of the organisms are so complex, it is probably impossible to establish a perfect classification of the communities. This is demonstrated by the fact that some animals occur in one habitat during high tide periods and in others during the periods of exposure to the air. Moreover, some animals are active and roam only when complete darkness prevails. These constantly recurring variations in the communities require that the terms used in classifying the units of animal societies must be plastic. It must also be understood that the limits of the units are local and more or less arbitrary.

There are two main methods which are followed in the classification of ecological units. One group of workers bases the classification upon the obvious variations in the physical and chemical environment of the organisms. The other group designates the biotic units according to characteristic aggregations of organisms.

It was first pointed out by Peterson ('15) and later emphasized by Shelford ('25) that the units of animal communities of the sea bottom should be based upon the distribution of species which are closely similar as to the physical and chemical requirements. This method has been followed in most of the recent marine ecological works, *e. g.*,, in Molander ('28) and Gislen ('30). In all of these cases the investigations were carried out over wide areas of the littoral and sublittoral in which it was possible to observe the limits of the broader ecological units. It is claimed by these writers that the animal aggregation is the best index to the limiting factors of the environment. The *association* is designated by those following Peterson's lead, as the fundamental ecological unit of biotic communities. There is obviously no agreement among these writers concerning the valuation of the association, and as a consequence there has developed much confusion in the terminology of the ecological literature in this respect.

Those who classify the communities according to the type of the habitat also use the term *association*. Here again, there is comparatively little unanimity in the conceptions of the unit.

This confusion will continue until the units can be more clearly defined and until they cease to be indefinite concepts. It is certain that more extensive quantitative investigations with more exact knowledge of the interrelationships of the animal aggregations will help to solve this problem.

There are certain species each of which tends to form a characteristic community in the area which it inhabits. That is, these forms alter the environment to such an extent that the area becomes a favorable habitat to some species and unfavorable to others. This condition may be brought about by one or more of several characteristics of the predominating species, such as size, numbers, or methods of living. In an area inhabited by such forms, the biological factors are found to be more pronounced than the physical factors and a more definite relationship exists between the members of the society. In cases where there is a pronounced interdependence among the organisms, these may be said to form an association and the species which *controls* the environment may be called a dominant. It is on this basis that the term *association* is used in the following pages.

On the other hand, there are certain species, for example *Littorina planaxis*, which do not take part in any of the complex animal societies but are restricted to certain niches of the habitat limited by physical or chemical factors or both. Such isolated species are usually found in places where conditions are very extreme and thus where only specially adapted forms can exist.

Any investigation dealing exclusively with the associations will omit many interesting forms. It will, therefore, fail to give a complete description of the ecological conditions existing within a given area. In the present report an attempt has been made to include all forms which occur in appreciable numbers, even though some of them do not constitute a part of a definite association of organisms.

In discussing the distribution of the organisms of the intertidal region

studied in the present investigation, the littoral has been divided into four vertical zones based upon the relative periods of exposure. As was noted in a previous sub-division (Tides), these zones are characterized by more or less definite communities whose limits are marked by obvious breaks in the faunal sequence. At the same time it should be emphasized that these zones do not correspond to the "associations" of other writers. Such a division has only a restricted applicability, but even so it is thought to be justifiable since it permits one to describe the faunal aggregates in this region in relation to the most pronounced local limiting factor, the tidal rhythms.

In brief, the following interpretations and considerations have been applied to the terminology of these ecological concepts in the present report:

1. *Littoral:* This is the area between the mean higher high water and the mean lower low water lines of spring tides.

2. *Supralittoral:* This is the area above mean higher high water level at spring tides which is inhabited by halobiotic forms.

3. *Zone:* This term has a restricted, more or less local, application in this report. It is used to designate a subdivision of the littoral, in the form of a horizontal strip. The development of the zone in the investigated area is connected either directly or indirectly with the physical environmental factors, especially the tides.

4. *Association:* This is an aggregation of organisms which is initiated by a single species and which depends for its existence upon this dominant form. It is a concept subordinate to that of the zone.

V.—Animal Distribution and Zonation

It has long been recognized by marine biologists that there is a definite zonation of the organisms found in the littoral. The most conspicuous elements marking this zonation are found among the plants and sessile animals. Upon the basis of these forms, the littoral has often been divided into several vertical zones. For example, King and Russell ('09) describe four zones characterized by both animals and plants; Pearse ('13) divided the littoral into four zones, one animal and three plant zones; Flattely and Walton ('22) recognize six. None of these writers offers any discussion of the factors which may be responsible for the zonation of the organisms.

Johnson and York ('15) recognize four littoral zones of the vegetation in Cold Spring Harbor, New York. They assert that the periods of exposure and submergence in the intertidal area are the most significant factors influencing the zonation of intertidal plants. Data are given to show the relative time of exposure of the foreshore at six inch intervals, but no correlation of exposure time with the plant zonation is indicated by these authors. However, when one plots the exposure curve from the figures given by these writers (ibid., p. 135), the result is of the same nature as that shown in Figure 7 of this paper. The limits of the upper and lower zones correspond very closely with the obvious bends in the exposure curve.

In a study of the littoral fauna and flora of Church Reef in Wembury

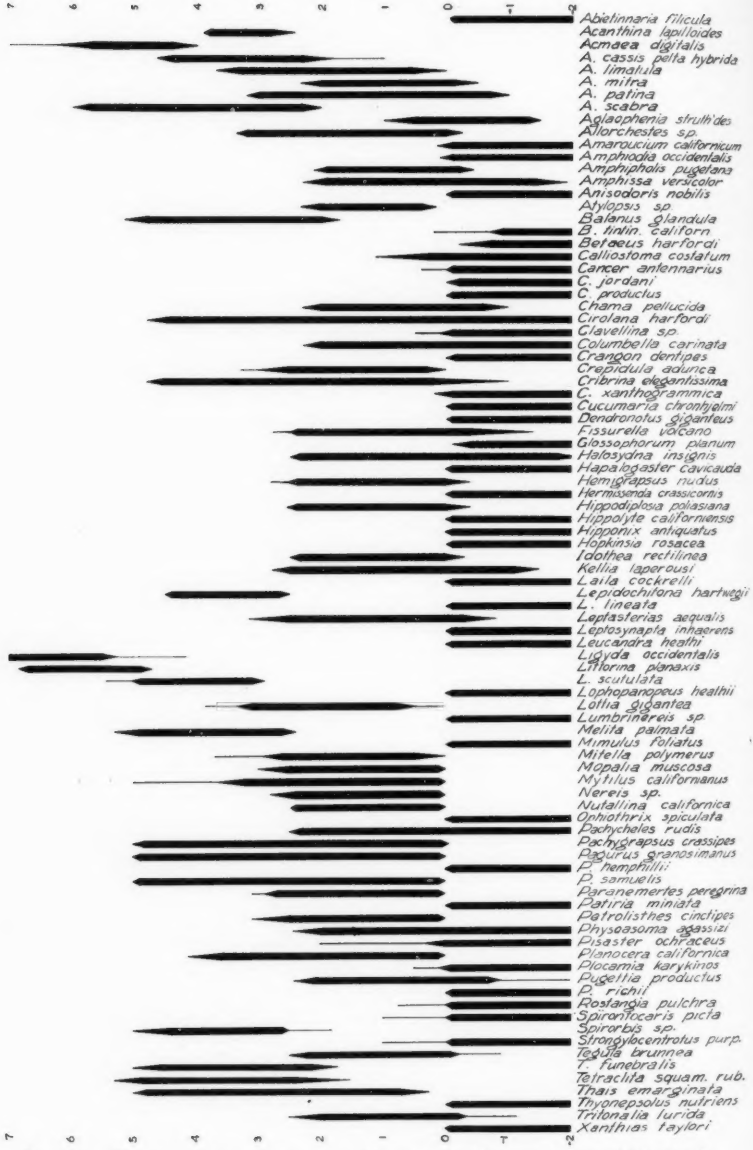


PLATE 1. Diagram showing the upper and lower limits of species of intertidal animals.

Bay, England, Colman ('33) points out the pronounced effect which the periods of exposure have upon the vertical distribution of the organisms. By determining the upper and lower limits of 22 species of plants and animals he shows that the most critical levels in the Wembury area are: "(a) between Mean and Extreme Low Water Springs; (b) between Mean Low Water Neaps and Springs; (c) at Extreme (Lowest) High Water Neaps."

From an analysis of the quantitative data, given in Table 10, and from the levels shown in the profile of the ecological cross section (Plate 2), it was possible to determine the upper and lower limits of the most common species found within the area studied in Monterey Bay. The results of this analysis are shown in the diagram of Plate 1. Some sources of error caused by the irregular nature of the rock surfaces were checked in the field by means of a transit level in order that the diagram would show, as nearly as possible, the exact vertical limits between which the organisms ranged.

It should be noted here that the predicted tide levels in areas exposed to an appreciable wave action can not be correlated exactly with the biotic limits. This fact has been pointed out by Orton ('29) and by Colman ('33). These investigators have allowed two feet for the extent of the "splash zone."

In an area such as the one under consideration, there would be no justification for allowing a strip of uniform width throughout the transect to represent the spray zone. In the outermost portion of the section, where surf action is great, especially during the stormy winter months, the upper limits of the ranges may be extended several feet, while in the innermost protected region the exaggeration of the levels is much less pronounced. The height of the splash zone also varies greatly with the seasons of rough and calm weather. Because of these variable factors of the surf, no allowance has been made for the wave action.

The limits of the ranges of the organisms found in the exposed littoral are less definite than those of the protected littoral. This condition is a result of the more irregular nature of the periods of submergence and emergence in the exposed area. In Plate 1, this has been indicated in some cases by a variation in the width of the lines; see, for example, *Mytilus californianus*.

The total number of upper and lower limits of the ranges of the organisms and the total number of species occurring between intervals of two-tenths of a foot in the intertidal were obtained from the data given in the graphic diagram of Plate 1. These figures are shown in Table 4 and are plotted in Figure 11.

The figures show three significant breaks in the faunal sequence of the intertidal area of this region. By far the most pronounced of these breaks is found at the level of mean lower low water, the zero of the tide tables. Many sublittoral inhabitants extend up into the littoral as far as the zero tide level but very few of them extend beyond this point. This is undoubtedly connected with the fact that above the mean lower low water level there is a sudden increase in the number of hours of exposure to which the organisms are subjected, as is shown in Figure 7.

Between the five and six foot levels there is also a definite change in the fauna, marked by the upper limit of the range of *Balanus glandula*. Several species of animals which are closely associated with these barnacles are not found above the five foot level. Between these levels, too, there is a marked change in the exposure curve as shown in Figure 7.

The distinct changes in the faunal sequence at the two levels, zero and five feet, thus appear to be the direct results of the relatively sudden changes in the amount of exposure at these levels. Furthermore, in each case, the level is most definitely marked by the upper limits of sessile animals.

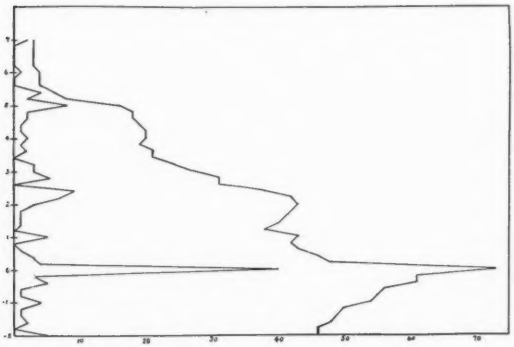


Fig. 10. Graph showing the total number of upper and lower limits of the ranges of organisms (left) occurring between the intervals of two-tenths of a foot.

TABLE 4. Total species and total upper and lower limits at intervals of 0.2 feet.

Level	Total Species	Total Limits	Level	Total Species	Total Limits
7.0	3	2			
6.8	3	0	2.4	38	9
6.6	3	0	2.2	42	7
6.4	3	0	2.0	43	3
6.2	3	0	1.8	42	1
6.0	4	1	1.6	41	1
5.8	4	0	1.4	40	1
5.6	4	0	1.2	38	0
5.4	6	4	1.0	43	5
5.2	8	2	0.8	42	0
5.0	16	8	0.6	43	1
4.8	18	2	0.4	46	3
4.6	18	2	0.2	48	4
4.4	19	1	0.0	73	40
4.2	20	1	–0.2	61	3
4.0	20	2	–0.4	61	5
3.8	19	1	–0.6	56	1
3.6	21	2	–0.8	55	1
3.4	21	0	–1.0	54	4
3.2	24	3	–1.2	50	1
3.0	27	3	–1.4	49	1
2.8	31	6	–1.6	48	2
2.6	31	0	–1.8	46	0

A third critical level occurs between the tide levels of two and three feet. The animal limits which mark this level are scattered through a vertical distance of one foot. In other words, this level is not so sharply defined as the other two.

The middle level appears to be the direct result of the heavy growth of *Pelvetia* and *Fucus* which are attached to the rocks of this area. The upper limit of this algal belt occurs at 3.5 feet. It forms by far the most obvious and striking line to be found in the littoral of this region (Fig. 11). The

Fig. 11. View of the intertidal area showing the prominent line formed by the upper limit of the Pelvetia-Fucus belt and the lower limit of the *Balanus glandula association*.

heavy growth of the fronds of the algae covers a belt between the levels of two and three feet. It is within this belt that the upper limits of the ranges of a number of intertidal animals are found.

Practically all of the animal species found in the zone between the zero and three foot levels are roving forms; and there is a very close ecological relationship between the fauna and the flora existing in the area. The rock surfaces retain their moist condition throughout the periods of exposure since they are covered by the algal fronds. The covering of the algae also protects the area from strong insolation. Thus a number of types of animals such as limpets, chitons, and snails which wander about during periods of darkness and at high tide periods, are to be found only beneath the layer of algae during times of exposure. Since all of the quantitative data presented was

collected during the hours in which the area was exposed to air and sunlight, these factors of exposure apparently account for the definite critical level in faunal distribution which is noted at this point. This is an excellent example of the difficulty facing the ecologist in his attempt to classify the animal communities noted above. The classification accepted in this report is intended to be a practical one. It holds for the low tidal periods when the ecologist is at work but not for the high tide intervals. During the low tidal periods a concentration and during the high tidal periods a scattering of the animals occurs.

The upper limit of the *Pelvetia-Fucus* habitat which is so definitely marked at the 3.5 foot level may be the result of tidal frequencies. It corresponds exactly with the point in the littoral which is crossed most frequently by the oscillating tidal waters (Fig. 12). The zonation of the animals in this area thus appears to be caused by the tide. The effect of the tide is partly direct, partly indirect through its influence over the *Pelvetia-Fucus* belt.

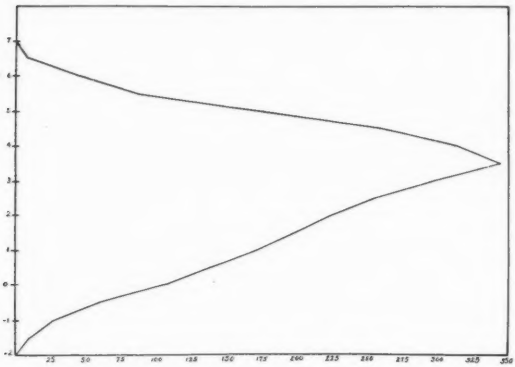


Fig. 12. Graph showing the frequency of the tidal waves at intervals of two-tenths of a foot in the intertidal area. (Data taken from Tide Tables.)

The middle faunal level is further emphasized by the lower limit of *Balanus glandula*. The range of this barnacle ends abruptly along the level at which *Pelvetia* fronds cover the rock surface (Fig. 11).

On the rocks of the exposed littoral which do not support any growth of *Pelvetia* and *Fucus* the zone between zero and three feet is densely populated with *Mytilus californianus* and its associated faunas.

On the basis of this zonation of the littoral animals, the intertidal has been divided vertically into four zones. In the following pages, each of these zones with its main inhabitants is described and at the end of each description a table is given showing the species and numbers of individuals of each found in a representative square yard. At the end of the section is a table showing the quantitative distribution of ninety of the most commonly represented species found along the ecological transect.

1. Supralittoral

The only halobiotic species commonly found among the supralittoral rocks, above the high tide line, is *Ligyda occidentalis*. These large isopods are found in rock crevices high above the spray zone. They apparently constitute a transition form between the marine and terrestrial life which has not as yet completely lost its affiliation with the marine habitat. During low tide periods and particularly after darkness, they make excursions into the upper region of the littoral in search of particles of detritus which constitute their food.

Several species of insects and arachnids, as well as one lizard, not belonging to the halobiosis, were noted in the supralittoral but were not identified.

2. Littoral

Zone I. The uppermost zone of the rocky shore at first appears to be a barren area. A close examination, however, will reveal that it supports a thin coating of small algae, a meagre pasture upon which a few animals browse. Only those organisms which have the ability to survive long periods of exposure to the strong insolation and to the fresh water of the winter rains are able to survive in this habitat.

Littorina planaxis is the most characteristic animal on the rock surfaces of this zone. At low tide they are found congregated in cracks and crevices in which water is retained after the tide has receded. Exiccation experiments carried out in the course of this investigation have shown that these periwinkles can withstand a maximum period of not less than 64 days without being submerged in sea water.

Two limpets, *Acmaea scabra* and *A. digitalis*, are found in the lower half of this zone. The former species is numerous in the protected areas, while a small growth form of *A. digitalis* is most abundant on the exposed rocks. Since the splash zone in the exposed littoral extends much higher than in the protected littoral, *A. digitalis* appears to range up to a higher level than does *A. scabra*. The large "homing" specimens of *A. scabra*, however, have a higher range on the rocks which are not exposed to wave action.

In the highest tide pools a eurythermal copepod, *Tigriopus fulvus*, is extremely abundant in all seasons. The temperature of the water in these pools fairly often reaches 29° C. during the summer months, and was recorded as low as 3° C. in the winter of 1932.

Square No. 12 is typical of this zone. Its contents are given in Table 5.

Table 5. Contents of Square No. 12

Acmaea digitalis	2
Acmaea scabra	19
Ligyda occidentalis	4
Littorina planaxis	28
**Tegula funebralis* (small)	27

* In a shallow tide pool.

Zone II. The rock surfaces between the levels of three and five feet are densely inhabited by rock barnacles and their associated fauna. Horizontal surfaces are completely covered with *Balanus glandula* which are greatly elongated because of the crowded condition. The presence of these barnacles gives to this belt of the foreshore a characteristic physiognomy (Fig. 13). Practically all forms found in the zone are dependent upon the barnacles for food or for protection against desiccation.

Fig. 13. A characteristic view of the *Balanus glandula* habitat on the rocky shore of Cabrillo Point.

During the periods at which this habitat is exposed to the drying effects of insolation and winds, the small periwinkle *Littorina scutulata* retreats into the empty barnacle shells or into the spaces between the barnacles where moisture is retained for comparatively long periods. These snails do not secrete the mucus for attachment and protection as does *L. planaxis*. As soon as the area is covered with water, they begin to move about over the barnacles and scrape encrusting and mat-forming algae from the substratum.

Acanthina lapilloides is always found associated with *Balanus glandula* in areas which are protected from violent wave action. They are easily detached from the rocks and hence are never found in the exposed littoral. Their food consist of the rock barnacles and of the small littorines. The peculiar feeding habits of this predaceous gastropod will be described later in another paper.

Three species of *Acmaea* are found in this zone. Small specimens of *A. scabra*, ranging from 3 to 10 mm. in length, are numerous among the barnacles. *A. limatula*, the file limpet, is abundant on the shaded vertical

rock faces at this level. These habitats, protected from the direct sunlight, present a fairly smooth surface due to the heavy growth of film-forming algae. A small growth form of *A. digitalis* is very common in the *Balanus* habitat of the exposed rocks.

In the tide pools of Zone II, *Cribrina elegantissima, Pagurus samuelis, P. granosimanus, Tegula funebralis,* and *Leptasterias aequalis* are found. These forms also occur beneath moist rocks at this level.

Table 6 gives the contents of a typical square of this level.

TABLE 6. Contents of Square No. 24

Acanthina lapilloides	6
Acmaea limatula	4
Acmaea scabra	361
Amphithoe sp.	Rare
Balanus glandula	14,000
Cirolana harfordi	Rare
Cribrina elegantissima	44
Leptasterias aequalis	9
Littorina scutulata	378
Pagurus granosimanus	23
Pagurus samuelis	18
Spirorbis sp.	Common
Tegula funebralis	37

Zone III. In the intertidal area studied in this survey there is, between the levels of zero and three feet, a distinct difference between the fauna of the protected littoral and the fauna of the exposed littoral. For this reason, the species of the two habitats are treated separately.

a. *Protected rock habitat:* The protected rocks of this zone are covered by a thick growth of algae which makes a uniform and sheltered habitat for the animals. The upper half of the zone supports a heavy layer of *Pelvetia* and *Fucus*. Of these two plants, the former is by far the most abundant alga in this region. The lower part of the zone is covered by several species of algae, most of which are brown.

This community is not characterized by any one dominant species such as one finds in the *Balanus* habitat above. On the other hand, it is easily distinguished by the presence of several species of animals, each of which occurs in moderate or small numbers. The most common species, arranged according to the degree to which they characterize this habitat, are *Acmaea cassis pelta, Leptasterias aequalis, Mopalia muscosa, Hippodoplosia pallasiana, Atylopsis* sp., *Tetraclita squamosa rubescens, Pachygrapsus crassipes, Spirorbis* sp., *Fissurella volcano, Pagurus samuelis* and *Idothea rectilinea.* These forms range throughout this zone of the littoral.

In the uppermost part of the zone, beneath the *Pelvetia* and *Fucus,* large specimens of *Tegula funebralis,* the black turban snail, are very abundant. At lower levels this form is replaced by the brown turban, *Tegula brunnea.* Individuals of the black species frequently carry dunce-cap limpets, *Crepidula adunca,* attached to their shells.

The two forms occurring in the greatest numbers are: an isopod, *Cirolana*

harfordi, and an undetermined amphipod of the genus *Atylopsis*. The amphipod was collected only in this zone but the isopod is found throughout the lower half of the littoral beneath the algae, rocks, and mussels.

Two gastropods, *Amphissa versicolor* and *Columbella carinata*, are common in this algal belt. Their lower limits extend down into the sub-zero zone. Another snail, *Tritonalia lurida*, is found only in Zone III.

In the "under-rock habitat" of this zone many characteristic species are found. *Pachycheles rudis*, *Hemigrapsus nudus*, and *Petrolisthes cinctipes* are

TABLE 7. Contents of Square No. 35

Acmaea patina	162
Amphipholis pugetana	4
Amphissa versicolor	24
Chama pellucida	1
Cirolana harfordi	Abundant
Columbella carinata	293
Cribrina xanthogramnica	1
Halosydna brevisetosa	8
Hippodiplosia pallasiana	Few
Kellia laperousi	4
Leptasterias aequalis	10
Pachycheles rudis	122
Pagurus samuelis	35
Paranemertes peregrina	Few
Pentidotea resecata	19
Petrolisthes cinctipes	9
Physcosoma agassizi	14
Pisaster ochraceus	4
Planocera californica	25
Pugettia producta	9
Spirontocaris picta	47
Strongylocentrotus purpuratus	49
Tegula funebralis	4

always present beneath the rocks. Small specimens of *Pagurus samuelis* are abundant in this habitat. Other animals found under boulders are *Planocera californica*, *Leptasterias aequalis*, *Nereis* sp., *Physcosma agassizi*, *Amphipholis pugetana*, *Acmaea scutum*, *Kellia laperousi*, and small specimens of *Strongylocentrotus purpuratus*.

Table 7 gives the species and the number or representatives of each species found in a typical square yard of the protected littoral of Zone III.

b. *Exposed rock habitat:* There are certain organisms which apparently can survive only on the rocks which are subjected to severe wave action. *Mytilus californianus* forms beds several inches in thickness on the rocks of the surf swept area. *Mitella polymerus*, the goose barnacle, is most commonly found in clusters among the mussels. The owl limpet, *Lottia gigantea*, inhabits the smooth rock surfaces along the upper margin of the *Mytilus* beds.

Practically all of the other animals found at this level of the exposed littoral may be classified into two ecological groups. First, there are those forms which depend upon the mussels for protection against the intense force of the waves and for protection from desiccation. The second group includes

those animals which depend upon the mussels as a source of food . (See Hewatt, W. G., 1934).

The species commonly found beneath the mussel beds are *Cirolana harfordi, Petrolisthes cinctipes, Physcosoma agassizi, Allorchestes* sp., *Amphissa versicolor, Columbella carinata, Tegula brunnea, Pachygrapsus crassipes* and small specimens of *Strongylocentrotus purpuratus*. It should be noted here that the population corresponds very closely to that of the under-rock habitat of the protected littoral.

The most common predaceous animals of the zone are *Thais emarginata* and *Pisaster ochraceus*. The whelks are the greatest enemies of the mussels in this region since they ocur in such large numbers. *Leptasterias aequalis*, the six-rayed star, feeds on the small mussels, ranging from 2 to 10 mm. in length.

TABLE 8. Contents of Square No. 105

Acmaea digitalis	204
Allorchestes sp.	1052
Amphissa versicolor	80
Balanus glandula	448
Balanus tintinabulum californicus	4
Calliostoma canaliculatum	4
Calliostoma costatum	4
Cirolana harfordi	12260
Columbella carinata	8
Lacuna sp.	4
Leptasterias aequalis	4
Lottia gigantea	8
Mitella polymerus	556
Mytilus californianus	2452
Pachygrapsus crassipes	4
Petrolisthes cinctipes	720
Physcosoma agassizi	672
Strongylocentrotus purpuratus	32
Tegula brunnea	44
Thais emarginata	240

Balanus glandula extends lower on the exposed rocks than on the protected. On the protected shore, the lower limit of its range is very abrupt and definite. In exposed places these rock barnacles attach themselves to the mussels. This is especially true during the spawning season of the barnacles.

The population of a typical square yard of the exposed mussel habitat is given in Table 8.

Zone IV. The upper limit of this zone is the zero level of the tide tables. It is the level of the mean lower low tides and is the highest point reached by any of the sublittoral animals, with the exception of a few which are found beneath rocks of the higher littoral.

The lowest intertidal zone is the most productive area found along the rocky shore. In contrast to the higher parts of the littoral, there is not the great abundance of individual representatives of each species; but the number of species of animals greatly exceeds that of the higher zones. This is the

region most frequently visited by shore collectors in search of specimens of the rarer species.

This zone has no dominant species. In other words, it does not have a characteristic physiognomy so apparent in the *Mytilus* beds.

The most characteristic animals found between the zero tide level and the lowest range of the tides are hydroids, colonial tunicates and sponges. *Aglaophenia struthionides* and *Abietinaria filicula* are familiar hydroids of the area studied. *Amaroucium californicum* is the commonest colonial tunicate; and *Lissodendoryx noxiosa* is the prevalent sponge.

TABLE 9. Table contents of Square No. 90

Abietinnaria filicula	Abundant
Aeolidia sp.	2
Aglaophenia struthionides	Common
Amaroucium californicum	Abundant
Amphiodia occidentalis	10
Amphiporus bimaculatus	2
Amphissa versicolor	67
Anisodoris nobilis	4
Betaeus harfordi	19
Bugula nereitina	Abundant
Calliostoma canaliculatum	2
Calliostoma costatum	12
Cancer antennarius	4
Cancer jordani	3
Cancer productus	3
Caprella sp.	Abundant
Cardita subquadrata	6
Chama pellucida	6
Cirolana harfordi	Abundant
Clavellina sp.	112
Columbella carinata	281
Corynactis sp.	13
Crangon dentipes	24
Cucumaria chronhjelmi	17
Dendronotus giganteus	2
Dirona picta	3
Epiactis prolifera	7
Eudistylia polymorpha	9
Fissurella volcano	3
Halosydna brevisetosa	37
Hapalogaster cavicauda	2
Hermissenda crassicornis	4
Hopkinsia rosacea	12
Ischnochiton mertensii	3
Isociona lithophoenix	Common
Kellia laperousi	5
Laila cockerelli	5
Leptasterias aequalis	22
Leucosolenia eleanor	Common
Lissondendoryx noxiosa	Few
Lophopanopeus heathi	11
Lumbrinereis sp.	Common
Megatebennus bimaculatus	4
Mimulus foliatus	4
Modiolus capax	7

Mopalia muscosa	2
Nereis sp.	Abundant
Ophiothrix spiculata	7
Orthopyxis caliculata	Common
Pachycheles rudis	62
Pagurus granosimanus	Common
Pagurus hemphilli	Common
Petrolisthes cinctipes	22
Physcosoma agassizi	127
Pisaster ochraceus	2
Plocamia karykinos	Common
Pododesmus macroschisma	4
Pugettia producta	2
Pugettia richii	4
Rhabdodermella nuttingi	Common
Rostangia pulchra	3
Saxicava arctica	12
Sertularia pulchella	Abundant
Spirontocaris picta	Common
Strongylocentrotus purpuratus	17
Styela stimpsoni	10
Synalpheus lockingtoni	2
Tanystylum intermedium	Abundant
Tegula brunnea	30
Tegula funebralis	3
Thyonepsolus nutriens	3
Xanthias taylori	3

The thick beds of sponges and tunicates offer an ideal habitat for shelter-seeking forms. Beneath the masses of colonial animals are found many retiring organisms such as the pistol shrimps, *Crangon dentipes, C. bellimanus* and *Synalpheus lockingtoni;* crabs, *Petrolisthes cinctipes, Pachycheles rudis, Lophopanopeus heathi, Xanthias taylori,* and *Hapalogaster cavicauda;* the isopod, *Cirolana harfordi;* the prawn, *Spirontocaris picta;* and the worms, *Halosydna brevisetosa, Nereis* sp., *Lumbrinereis* sp., *Physcosoma agassizi,* and *Eudistylia polymorpha.*

The hermit crabs are mainly represented in this sub-zero zone by *Pagurus hemphilli* and *P. granosimanus.*

There are a great number of different species of nudibranchs living on the substratum of this zone; for example, *Anisodoris nobilis, Hermissenda crassicornis, Hopkinsia rosacea,* and *Rostangia pulchra.*

Seventy-four species of animals were recorded from one square yard of the lowest littoral unit. The quantitative analysis of this square yard is given in Table 9.

3. Seasonal Migrations

After the preliminary quantitative survey of the transect was completed, it was possible to select typical squares, each of which was representative of a fairly homogeneous portion of the transect. A recounting of the inhabitants of these typical squares was made during each season of the year. In this way any pronounced seasonal migrations of the animals could be detected.

O'Donoghue (1924) found that *Pisaster ochraceus* and *Evasterias*

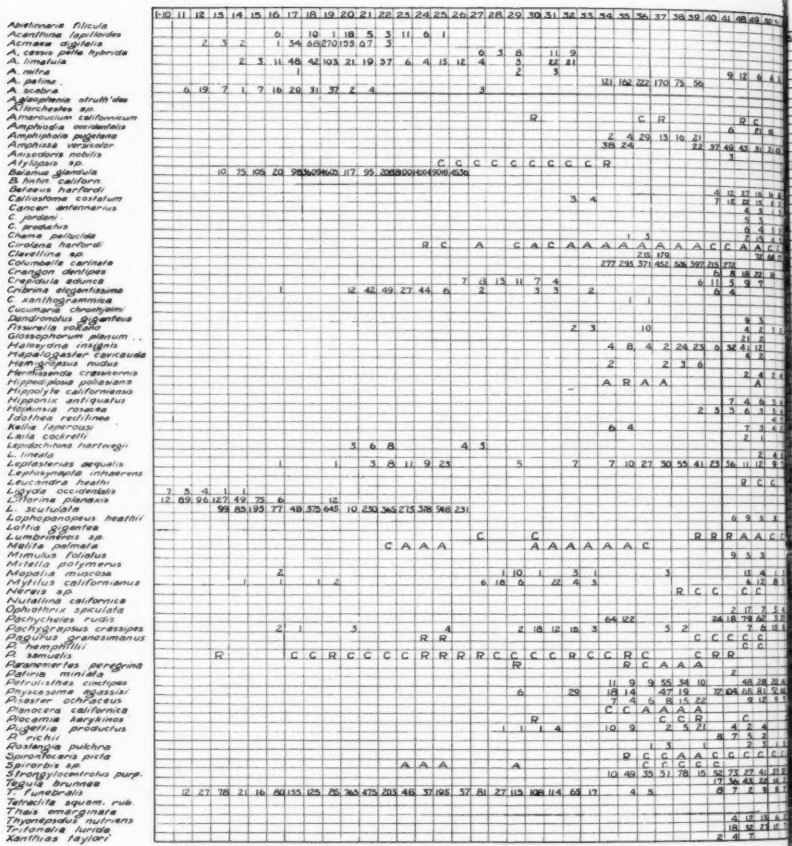
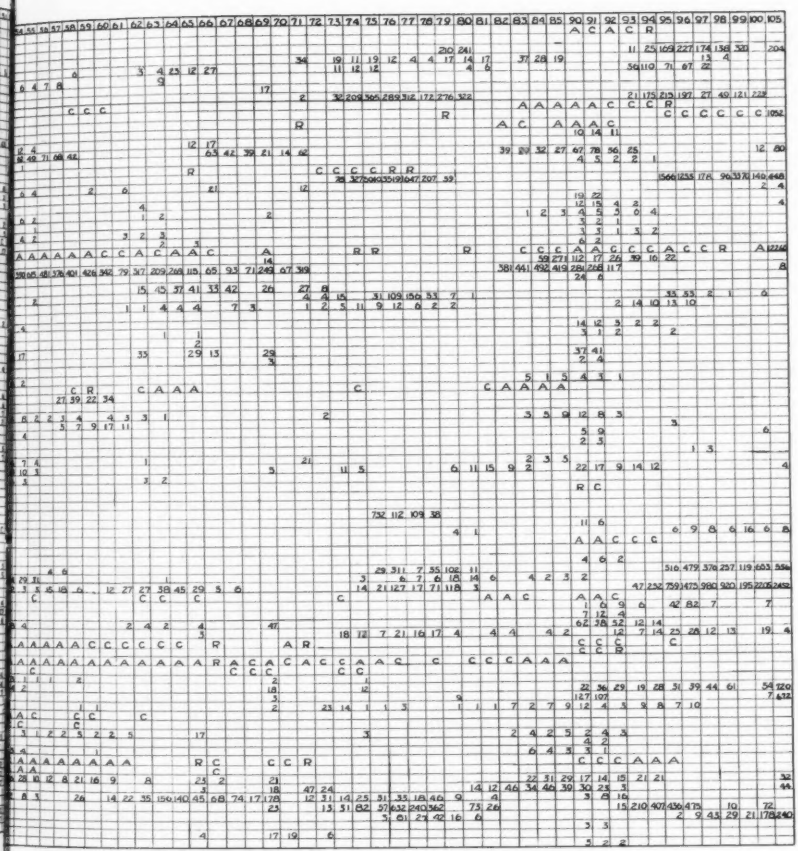


TABLE 10. Quantitative distribution of 90 of the most common species of anim
it was impossible to count individuals the relative population of the species is indic



species of anim
pecies is indic

ound along a transect across the intertidal region at Cabrillo Point. Cases in which
y: A—abundant; C—common; R—rare.

troschelli, the two common starfishes of the littoral of Departure Bay, British Columbia, migrate to a subtidal level during the hot summer months and return to the intertidal as the cooler season approaches. Seasonal migrations of this and other kinds are known from various regions where the vicissitudes of the seasons are more or less severe, for instance, along the Scandinavian Peninsula.

This phenomenon was not evident in the case of the Monterey Bay fauna. The small variations in the air and water temperatures of Monterey Bay probably account for the absence of seasonal migrations in this area. The marine climate of this region is, indeed, in this respect quite unique for the temperate seas.

The results of the periodic rechecking of the animal populations along the transect were not, however, altogether negative. It was noted that a generally lower level is obtained by *Leptasterias aequalis* during the breeding season. These six-rayed starfishes are found in the *Balanus glandula* habitat at all seasons except in late spring during which time they are brooding their young beneath the *Pelvetia* fronds.

The predaceous snail, *Acanthina lapilloides*, also migrates downward during the spawning season.

On account of the small changes in the number of specimens of the various species present during the different seasons, the results were not considered significant enough to justify the inclusion of these seasonal data in the present section. The examples given in the tables for each zone must suffice to illustrate the relative frequency of the species at all seasons.

VI.—Food Relationships

Generally speaking, in an intertidal community the basic food supply of the animals is of four main types, as follows:

1. *Larger benthonic plants.* These consist mainly of algae, although in certain regions a few phanerogam genera are more or less important, even playing the dominant role in particular localities. In the warmer parts of the oceans, the benthonic plants of large sizes are subordinate, while in the cold and temperate seas, the brown algae, especially, constitute a very conspicuous food component in the communities of the intertidal and subtidal regions. As a consequence, what is stated below in regard to the significance of these plants has a distinctly limited application. Probably the most striking, not to say paradoxical, result brought forth by the investigation of the food relations of the coastal regions is that, in spite of the enormous productivity of organic matter represented by the growth of the larger benthonic plants, nevertheless, relatively few of the animals feed directly upon these forms while they are still alive. The enormous algal pastures along the edges of the continents serve the animals almost exclusively as a substratum and as a means of protection, and hardly at all as a direct source of food.

2. *Encrusting or mat-forming algae.* These algae are usually very small, predominantly microscopic forms, a large number of them being diatoms.

They cover practically all surfaces of the foreshore; they even penetrate above the regions generally covered with water where they form an inconspicuous but important pasture. Many animals subsist by browsing on this filmy growth. Most important among the browsers are certain gastropods.

3. *Plankton.* Enormous quantities of plankton are formed, particularly in the colder and temperate waters. The warmer regions are comparatively barren of plankton and of large benthonic algae. This plankton material is constantly carried over the foreshore by currents and tidal streams and is sprayed over the higher levels of the coast belt by the waves. A large number of the animals feed on this supply, especially on the microscopic constituents.

4. *Detritus.* The particulate matter, or detritus, which is formed by the disintegration of plants and animals, is of great importance as a source of food in most intertidal areas. Included in this material are, of course, enormous quantities of micro-organisms. These unquestionably are of profound importance as a direct source of nourishment for the higher animals, although so far no attempt has been made to estimate their relative significance. Most of the detritus in the intertidal belts of the cold and temperate seas is derived from the larger benthonic plants. It is in this condition that these plants mainly contribute to the food cycles of these regions.

Thus the first of these four types of food always seems to be of but slight significance. It may also be stated with safety that the second type is of subordinate importance (with possible exceptions in certain habitats of the tropical seas). The last two types are unquestionably the dominant ones. There is disagreement, however, among the ecologists concerning the relative value of the living plankton and of the detritus as a food supply for bottom-dwelling marine animals. The early investigators were prone to draw too broad conclusions from observations in localized areas. A large number of recent investigations have shown that these early generalizations concerning the food supply of marine organisms were not justified. No sufficiently broad, quantitative survey has been carried out in this field, and thus the problem must still be considered as unsolved.

MacGinitie (1935, p. 648) emphasizes the fact that the plankton constitutes a very insignificant link in the food chains of the mud-living animals of Elkhorn Slough, California. In this environment, where bacterial action is enhanced by relatively high temperatures and by the enclosed nature of the habitat, it was found that detritus formed by far the greater portion of the basic food supply. Most of the inhabitants live beneath the surface and pass the mud, rich in detritus, through their digestive tracts. This condition, however, applies only to organisms found in sloughs and similar surroundings.

According to the work of Blegvad (cit. Shelford, 1929, p. 114), the living plankton is not significant as a food for bottom living forms of the sea. Blegvad states that

> Detritus forms the principal food of nearly all the invertebrates of the sea bottom, next in order of importance being plant food from fresh benthos plants. The value of the live plankton in this connection is absolutely minimal, amounting in any case to nothing more than an indirect significance through the medium of the plankton copepods.

Here again, too broad conclusions should not be drawn from observations made in a local area. The conditions of the Danish coastal waters, upon which Blegvad based his conclusions, are far from typical of coastal regions in general. The broad expanse of shallow water off the coast of Denmark, especially the Lim Fjord where most of these observations were made, permits an extremely abundant growth of Zostera and other marine plants. A large supply of detritus results from the disintegration of these plants. Even moderate wave activity in these shallow waters keep a part of the detritus almost continuously in a state of suspension so that the so-called "plankton feeders," such as mussels and barnacles, probably subsist to a very large extent on suspended detritus.

In the region investigated in the present work there is an abundance of algal growth, although limited in area due to the steep slope of the bottom. The supply of micro-plankton is also extremely plentiful. It is certain that this living plankton forms an important link in the food chains of the bottom living invertebrates of the area. The stomach contents of a large number of mussels and barnacles, which live on the minute food, were examined. These examinations revealed the presence of many of the dinoflagellates and diatoms which are known to be common in the adjacent waters. The contents of the lower portion of the alimentary canals of these animals showed a decidedly increased proportion of the empty shells of these plankton organisms. This indicated that these organisms were digested and hence that live plankton is used as a food.

Several samples of sea water from the intertidal region were centrifuged and examined. The results showed a high percentage of living micro-plankton as well as much detritus. Bigelow and Leslie (1928, p. 530) examined the waters of Monterey Bay in the mid-summer of 1928. Even during this season of supposedly low productivity in temperate seas, these investigators found the quantity of phytoplankton in the surface waters to be very high. They estimated the average diatom production at that time to be over one million cells per liter of surface water in the Bay.

It should be emphasized that these statements are not to be interpreted as implying that live micro-plankton forms the most important food of plankton feeders. Generally speaking, detritus when strongly particulated, is very difficult to estimate quantitatively. No attempt was, therefore, made to establish the relative value of these two types of food. Both of them unquestionably are essential. The live plankton is, however, not subordinate as suggested by investigators of other habitats but on the contrary it is a very essential component.

Because of pronounced differences in the feeding habits of the organisms of the exposed and protected areas, the food cycles of the two regions have been discussed separately.

a. *Protected habitat:* In the protected part of the littoral *Balanus glandula* is the most abundant form which obtains its food from the material suspended in the surrounding water. As soon as these barnacles are covered by the tidal waters, they begin feeding. At the lower level of this community are found

sponges, hydroids, dunce-cap limpets *(Crepidula adunca)* and *Spirorbis* which also feed on the suspended detritus and its bacteria, as well as on the living plankton. Beneath stones, *Petrolisthes cinctipes* is found straining suspended matter from the water.

Next in abundance to the plankton and suspended detritus feeders are the forms which scrape encrusting and mat-forming algae, inclusive of benthonic diatoms, from the rock surfaces. This group of browsing organisms consists mainly of gastropod molluscs such as periwinkles, turban snails, and limpets. In Zone I, this type of feeder is represented by *Littorina planaxis* and two species of *Acmaea: digitalis* and *scabra.* In Zone II, *Littorina scutulata, Acmaea cassis pelta,* and *Tegula funebralis* scrape the rock surfaces for food. The snails, *Columbella carinata, Amphissa versicolor, Tegula brunnea,* and the limpet *Fissurella volcano,* also of this feeding type, are abundant at the lower levels.

The only organism in the protected habitat which is known to feed on the living benthonic growth of large algae is *Pugettia producta.* The stomach contents of a number of these forms revealed the presence of small rectangular pieces of the fronds of algae, mostly *Iridaea.*

Among the predaceous species of the protected area, *Acanthina lapilloides* is the most numerous. Members of this species feed mainly upon the barnacles but they have been seen devouring periwinkles. The interesting feeding habits of this form are described elsewhere.

Leptasterias aequalis feeds upon a variety of animals, such as barnacles, littorines, young limpets and young snails.

An examination of the stomach contents of several species of fishes, for example, *Clinocottus analis, Montereya recalva, Xiphidion ruprestre,* found in the lower tide pools and under rocks in this area, showed that their food supply consisted mainly of amphipods and isopods.

The pure detritus feeders include a large number of species, most of which are represented by relatively few individuals. Some of the most important animals which subsist on the disintegrating parts of other organisms are: *Cirolana harfordi, Pentidotea resecata, Pachygrapsus crassipes, Hemigrapsus nudus, Pachychelus rudis, Pagurus samuelis, P. granosimanus,* and *Halosydna brevisetosa.* A number of burrowing annelids also comes under this category.

A diagram showing the main chains in the food cycles of the protected littoral is given in Figure 14.

b. *Exposed habitat:* The food relationships of the animals in the exposed littoral are shown in Figure 15. The main differences between the protected and exposed habitats consist in the presence of the large numbers of *Mytilus californianus* found in the exposed habitat. This is a form which subsists on microplankton and suspended detritus. Plankton feeders, other than Mytilus californianus, which are found in abundance in this habitat, are the rock barnacles, *Balanus glandula* and *Tetraclita squamosa rubescens,* and the goose barnacle *Mitella polymerus.* The two rock barnacles are restricted to areas which are not favorable for the growth of the mussels, while the goose barnacle

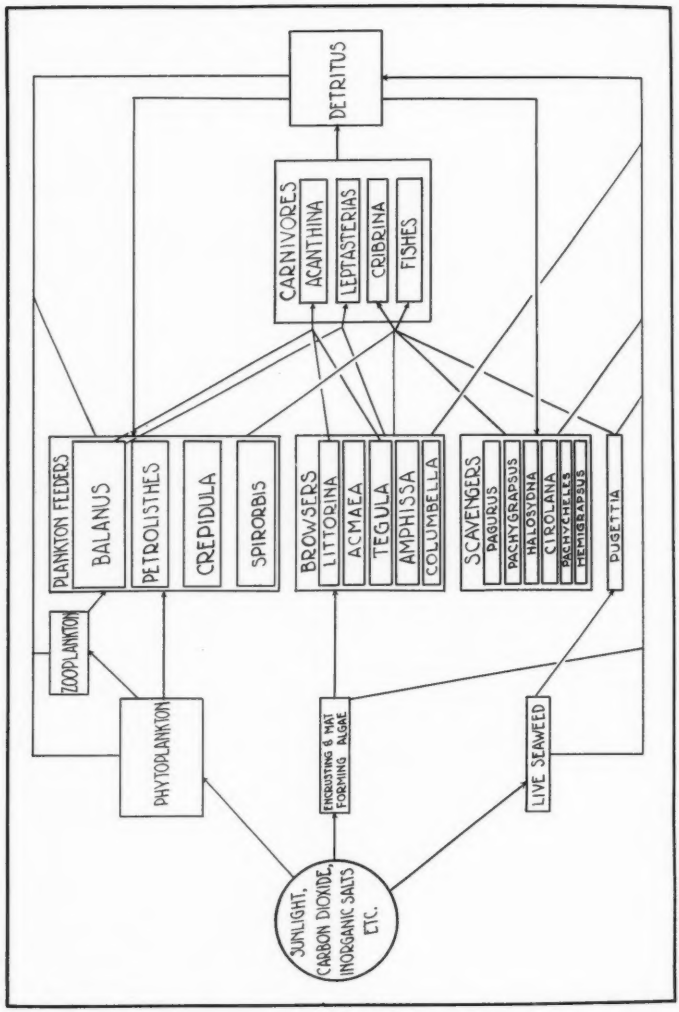


Fig. 14. A diagram of the food cycle of the animals found on the protected littoral rocks of Cabrillo Point.

Fig. 14. A diagram of the food cycle of the animals found on the protected littoral rocks of Cabrillo Point.

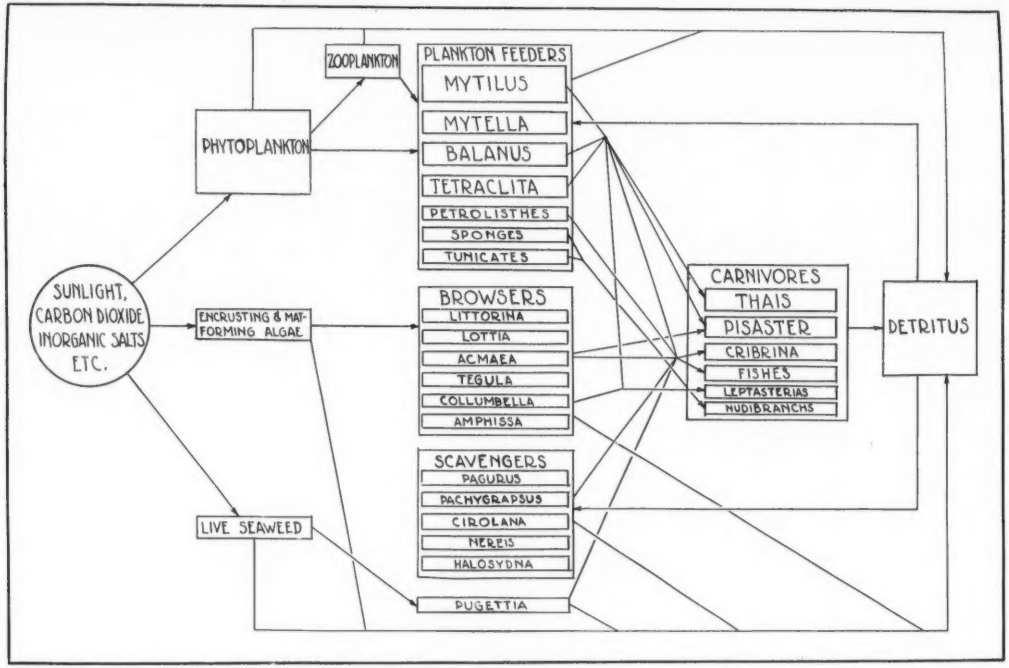


Fig. 15. A diagram of the food cycle of the animals in the exposed littoral of Cabrillo Point.

is only found associated with these bivalves. Beneath the mussel beds, *Petrolisthes cinctipes* feeds on the plankton and suspended detritus.

On the protected sides of vertical rock faces in the surf-swept region, there is a small, green anemone, thought to be identical with *Cribrina elegantissima,* which apparently feeds to a great extent upon the plankton and nectonic invertebrates. In a large number of individuals examined, the gastrovascular cavity revealed the presence of partially digested copepods, isopods, and amphipods, as well as many diatoms and dinoflagellates. It is supposed that these anemones are partially nourished by the large quantities of symbiotic algae which are found in their tissues. Along the water channels, at lower levels, many hybroids, bryozoa, sponges, and tunicates feed on the microplankton and on the bacterial contents of the suspended detritus.

Among the organisms which scrape their food from the substratum, *Littorina scutulata* is the most abundant form on the surfaces covered by rock barnacles. Here, also, are found numerous specimens of *Acmaea scabra* and *A. digitalis* which range down into the upper part of the mussel habitat. A small black species of *Acmaea,* which was not determined, is the most common limpet of the mussel beds. These animals are found scraping food from the mussel shells to which they are attached. *Lottia gigantea,* also this type of feeder, is found only on the exposed rocks.

At the lower levels, thes nails, *Tegula brunnea, Calliostoma costatum, C. canaliculatum, Columbella carinata,* and *Amphissa versicolor,* are the most common browsing forms.

Pugettia producta feeds on the abundant algal growth at the lower levels of the exposed littoral.

The mussels, which are found in large numbers in areas exposed to wave action, furnish food for a variety of predaceous animals. *Thais emarginata,* the purple whelk, bores through the mussel shells and extracts the soft parts. *Pisaster ochraceus,* the common large starfish of this intertidal region, lives in the crannies and cracks at the base of the *Mytilus* beds and is found feeding on the mussels, especially during the night. The large green anemone, *Cribrina xanthogrammica,* is not an active enemy of the mussels but feeds upon the specimens which are torn loose by wave actions. During the stormy winter months, large mussels drop down into the channels which are thickly populated by the large anemones. The crabs, *Cancer antennarius, C. productus, Pachygrapsus crassipes,* and *Petrolisthes cinctipes* are also eaten by these anemones. The food of *Leptasterias aequalis* found in this area consists mainly of small mussels, limpets, and barnacles.

Many of the subtidal fishes visit the intertidal zone during periods of high tide, but little is known of their food habits. However, the mussels, limpets, and crabs probably form a large part of their food supply.

Pagurus hemphilli, Pachygrapsus crassipes, Cirolana harfordi, Nereis sp., and *Halosydna brevisetosa* depend for their food upon decaying remains; *i.e.,* they are the detritus feeders of the exposed littoral.

VII.—Systematic List of Species

PORIFERA

Isociona lithophoenix (de Laubenfels)
Leucandra heathi (Urban)
Leucosolenia elenor Urban
Lissodendoryx noxiosa de Laubenfels
Ophalitospongia pennata (Lambe)
Plocamia karykinos de Laubenfels
Reneira cineria Bowerbank

COELENTERATA

Abietinnaria filicula (Ellis and Solander)
Aglaophenia struthionides (Murray)
Corynactis sp.
Cribrina elegantissima (Brandt)
Cribrina xanthogrammica (Brandt)
Epiactis prolifera Verrill
Orthopyxis caliculata (Hinds)
Plumularia setacea (Ellis)
Sertularia pulchella (d'Orbigny)

PLATYHELMINTHES

Planocera californica Heath & McGregor

NEMERTINA

Amphiorus bimaculatus Coe
Micrura verrillii Coe
Paranemertes peregrina Coe

BRYOZOA

Bugula neritina (Linnaeus)
Hippodoplosia pallasiana (Moll)
Membranipora tehuelcha (d' Orbigny)

ANNELIDA

Arenicola sp.
Eudistylia polymorpha (Johnson)
Halosydna brevisetosa Kinberg
Polynoe lordi Baird
Lumbrinereis sp.
Nereis sp.
Sabellaria sp.
Serpula columbiana Johnson
Spirorbis sp.

GEPHYREA

Physcosoma agassizi Keferstein

ARTHROPODA

CRUSTACEA

Allorchestes sp.
Amphithoe sp.
Atylopsis sp.
Balanus glandula Darwin
Balanus tintinnabulum californicus Pilsbry
Betaeus harfordi (Kingsley)
Cancer antennarius Stimpson
Cancer jordani Rathbun
Cancer productus Randall
Caprella sp.
Cirolana harfordi (Lockington)
Crangon bellimanus (Lockington)
Crangon dentipes (Cuerin)
Exosphaeroma oregonensis (Dana)
Hapalogaster cavivauda Stimpson
Hemigrapsus nudus (Dana)
Hemigrapsus oregonensis (Dana)
Hippolyte californiensis Holmes
Idothea rectilinea (Lockington)
Ligyda occidentalis (Dana)
Lophopanopeus heathii Rathbun
Melita sp.
Mimulus foliatus Stimpson
Mitella palymerus (Sowerby)
Pachycheles rudis Stimpson
Pachygrapsus crassipes Randall
Pagurus granosimanus (Stimpson)
Pagurus hemphilli (Benedict)
Pagurus samuelis (Stimpson)
Pentidotea resecata (Stimpson)
Pentidotea wosnesenskii (Brandt)
Petrolisthes cinctipes (Randall)
Polycheria osborni Calman
Pugettia producta (Randall)
Pugettia richii (Dana)
Scyra acutifrons Dana
Spirontocaris paludicola Holmes
Spirontocaris picta (Stimpson)
Synalpheus lockingtoni Coutiere
Tetraclita squamosa rubescens Darwin
Xanthias taylori (Stimpson)

ARACHNIDA

Pycnogonum stearnsi Ives
Tanystylum intermedium Cole

MOLUSCA

AMPHINEURA

Callistochiton crassicostatus Pilsbry
Ischnochiton magdalenensis (Hinds)
Ischnochiton mertensii (Niddendorff)
Katharina tunicata (Wood)
Lepidochitona lineata (Wood)
Lepidochitona hartwegii (Carpenter)
Mopalia muscosa (Gould)
Nuttallina californica (Reeve)
Placiphorella vollata Carpenter

GASTROPODA

Acanthina lapilloides Conrad
Acmaea asmi (Niddendorff)
Amaea cassis pelta hybrida (Eschscholtz)
Acmaea digitalis Eschscholtz
Acmaea insessa (Hinds)
Acmaea limatula Carpenter
Acmaea patina (Eschscholtz)
Acmaea scabra Gould
Aeolida herculea Bird
Aeolidia papillosa Linnaeus
Amphissa versicolor Dall
Anisodoris nobilis (MacFarland)
Bittium eschrichtii (Niddendorff)
Cadlina marginata MacFarland
Calliostoma canaliculatum (Martyn)
Calliostoma costatum (Martyn)
Calliostoma gloriosum Dall
Columbella carinata Hinds
Crepidula adunca Sowerby
Crepidula nivea Adams
Dendronotus giganteus O'Donoghue
Diadora aspera (Eschscholtz)
Diaulula sandiegensis (Cooper)
Dirona picta MacFarland
Discodoris heathi MacFarland
Fissurella volcano Reeve
Haliotis cracherodii Leach
Haliotis rufescens Swainson
Hermissenda crassicornis (Eschscholtz)
Hipponix antiquatus Linnaeus
Hopkinsia rosacea MacFarland
Lacuna porrecta Carpenter
Laila cockrelli MacFarland
Lamellaria stearnsiana Dall
Leptothyra carpenteri (Pilsbry)
Littorina planaxis Philippi
Littorina scutulata Gould
Lottia gigantea Gray
Megatebennus bimaculatus (Dall)
Philodina sp.
Polycera atra MacFarland
Pseudomelatoma torosa Carpenter
Purpura nuttallii (Conrad)
Rostangia pulchra MacFarland
Tegula brunnea (Philippi)
Tegula funebralis (Adams)
Thais emarginata (Deshayes)
Triopha carpenteri (Stearns)
Triopha maculata MacFarland
Tritonalia interofossa (Carpenter)
Tritonalia lurida (Middendorff)

PELECYPODA

Cardita subquadrata (Carpenter)
Chama pellucida Sowerby
Hinnites giganteus Gray
Kellia laperousi (Deshayes)
Mytillimaria nuttallii Conrad
Modiolus capax Conrad
Mytilus californianus Conrad
Pecten circularis Sowerby
Pododesmus macroschisma Deshayes
Saxicava arctica (Linnaeus)

CEPHALOPODA

Paroctopus apollyon (Berry)

ECHINODERMATA

Amphiodia occidentalis (Lyman)
Amphipholis pugetana (Lyman)
Cucumaria chronhjelmi Theel
Henricia leviuscula (Stimpson)
Leptasterias aequalis (Stimpson)
Leptosynapta inhaerens (Muller)
Ophiothrix spiculata LeConte
Patiria miniata (Brandt)
Pisaster ochraceus (Brandt)
Strongylocentrotus franciscanus (Agassizi)
Strongylocentrotus purpuratus (Stimpson)
Thyonepsolus nutricns Clark

CHORDATA

TUNICATA

Amaroucium californicum Ritter and Forsyth
Clavellina sp.
Glossophorum planum Ritter and Forsyth
Styella stimpsoni Ritter

VERTEBRATA

Clinocottus analis (Girard)
Dialarchus snyderi (Greeley)
Greeleya rubellio (Greeley)
Xiphidion ruprestre (Jordan and Gilbert)

Summary

On the southern margin of Monterey Bay, California, a transect, one yard wide and 108 yards long, across the littoral was subjected to an ecological study.

The area investigated is rocky and characterized by the unusual monotony of most of the factors of its physicochemical environment. For instance, the average annual range of the temperature of the surface water is only 2.5° C., from 11° to 13.5° C.; the salinity of the surface water exhibits variations between 32.12 and 33.82 grams of salt per liter and the water is apparently always saturated with oxygen; the average daily thermal range for the air, 11.1° C.; and fog prevails during the warmer part of the year. The most pronounced environmental factor is the tide, which is unequal, with striking differences particularly between the two daily low tides.

A quantitative and qualitative analysis of this ecological transect showed that there is a definite zonation of the intertidal animals in the area. Upon the basis of the accumulated data, the littoral of this area was divided into four vertical zones. The factors which cause this zonation are elusive in nature and thus are not readily determined. It was found, however, that two of the zonal limits located at the 0.0 and 5.0 foot levels, are closely correlated with the relative *lengths* of the periods of tidal exposure to which the animals are subjected. The remaining limit, represented by a less definite level between two and three feet above the zero tide level, corresponds to the upper limit of the area which is covered by the fronds of *Pelvetia* and *Fucus*. This faunal level may, indirectly, be due to the *frequency* of tidal exposures since the upper limit of the *Pelvetia-Fucus* growth coincides with the line across which the tide most frequently passes. This level in the animal zonation, however, is evidently the direct result of the protection against dessication and insolation afforded the animals by these algae.

It was also established that the limits of the ranges of some of the animals result rather from biological than physico-chemical prenomena. Interspecific relationships of food and shelter are particularly conspicuous. Examples of animals which are thus limited in their vertical ranges are, *Acanthina lapilloides*, *Thais emarginata*, and *Littorina scutulata*.

Some species have developed certain adaptations which enable them to occupy niches of the habitat where competition is less severe. For example, *Littorina planaxis* has penetrated into the upper littoral due to its capacity to withstand relatively long periods of exposure to air and fresh water. It also maintains its position on the foreshore by its ability to attach itself to the substratum by a mucous secretion. *Acmaea scabra*, on acount of its remarkable homing habit, can also live in the upper littoral.

With the exception of certain spawning migrations, no pronounced seasonal migrations were noted in the investigated area. This condition is undoubtedly the result of the extreme monotony of the physical and chemical environment.

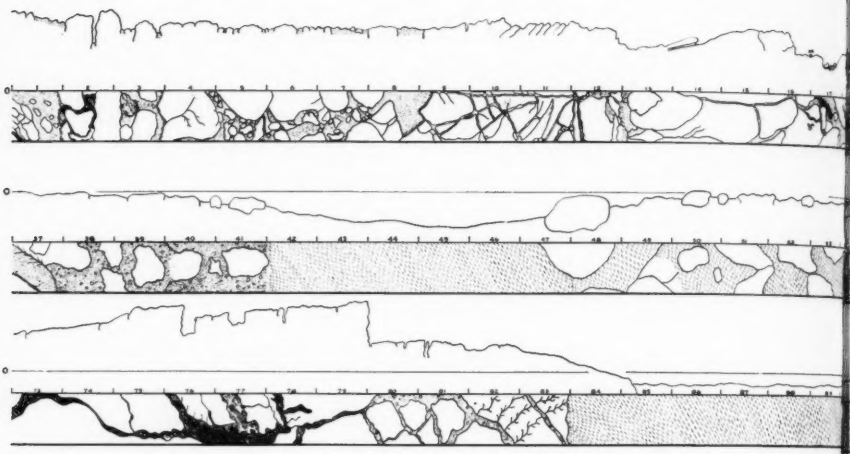


PLATE 2. A diagram showing a superficial and profile view of the ecological transect. The mean lower low water line is indicated on the chart. The first 12 squares represent an uneven rocky area characterized by many cracks and crevices in which loose boulders and sand are found. In squares 17, 18, 19 and 20 is located a high tidepool in which water is retained after the tide recedes. From squares 20 to 41 the basic granite projects above the sandy bottom and the space

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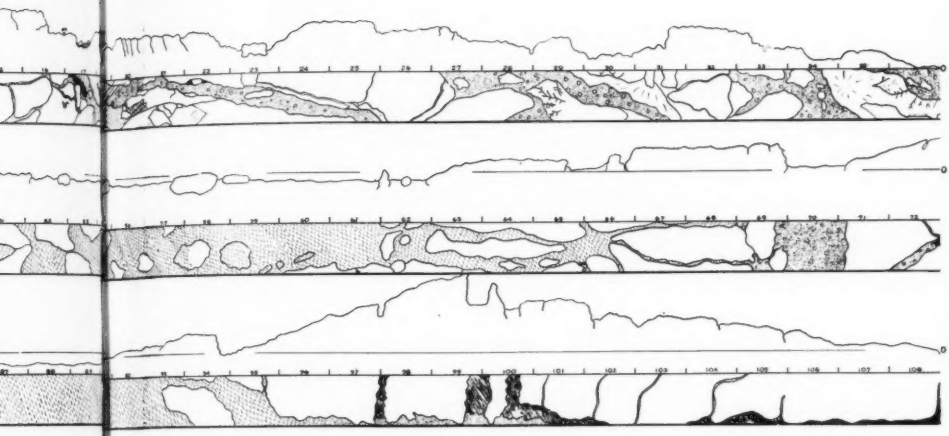

between the projections are filled with shell and sand and loose rocks. The transect crosses a permanent channel between the squares 41 and 48. A permanent tidepool covers the area between squares 49 and 63. Between squares 63 and 83 the surface is characterized by a granite projection which rises several feet above the zero tid level. Another water channel is shown between squares 85 and 90. The outermost granite projection is located between squares 90 and 108. This portion is the area which is most exposed to the wave action.

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Further Studies on North American Gyrodactyloidea

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In previous papers, I presented systematic and descriptive studies of 28 species of small gyrodactyloid trematode parasites of native fishes. This group has received but little attention from American zoologists. Recently, Mizelle (1936) described 12 additional species. This paper describes 13 species, thus bringing the total number of species up to 53. Two of these 53 species belong to the genus Dactylogyrus, seven belong to Gyrodactylus and the remaining 44 belong to the subfamily Tetraonchinae. I have already described five new genera for the native species of Tetraonchinae. In this paper three further new genera are established.

In an earlier contribution (Mueller, 1936) I suggested a terminology for the armature of the haptor in order to facilitate morphological description of this part. I also suggested a method of numbering the hooks, designed to homologize the hooks in different types of haptor. Mizelle accepts and extends the terminology advanced in this paper, but without any mention of my system of numbering the hooks, proposes a different system in which he numbers them in a linear series from the ventral to the dorsal side of the haptor in all forms, thus ignoring the shift in position of certain pairs of hooks in different types of haptor. Any system of numbering should be designed to show how the primitive arrangement has been modified. In my system the hooks were numbered consecutively in the primitive haptor only. In other types of haptor, in which the position of the hooks has been modified, the hooks were numbered with the purpose of showing the deviation from the primitive arrangement. In nearly all forms a pair of hooks lie close together on the median ventral anterior edge of the haptor. Since these can with certainty be identified in all species they are regarded as homologous in all forms, and are designated as pair number 1. The primitive arrangement of the other hooks can be found in such species as *Onchocleidus mimus*, or *Cleidodiscus robustus*, in which the haptor is wedge shaped, the bars non-articulate and similar, and the anchors all of the same form and size. In these the hooks lie in a simple series around the edge of the haptor, with the 7th pair posterior and median between the shafts of the anchors, as shown in my paper, Mueller 1936, figs. 13, 14. In such a species as *O. ferox*, the haptor has been drawn out axially, with the result that the 7th pair of hooks have been displaced to the rear, where they lie between the shafts of the ventral anchors, with their points directed toward the ventral surface. In species with articulate bars, the haptor is flattened and all four anchors are directed toward the ventral surface. What happens to the hooks in such a case can be observed in *Cleidodiscus oculatus*, in which, again, the 7th pair of hooks lie in contact with the ventral anchors, while pairs 1 to 6 are arranged in a series from the median anterior edge on back. In *Cleidodiscus*

fusiformis the arrangement is very similar, but the edge of the haptor is more expanded, and has carried the hooks of pairs 1 to 6 outward with it to a peripheral position. In *Cleidodiscus bursatus* it is clear that pair number 1, which already shows some tendency toward a central position in *C. oculatus,* has migrated still further toward the middle of the haptor, to lie close to number 7, while pairs 2 to 6 occupy a peripheral position on the edge of the greatly expanded haptor. Mizelle proposes to number the hooks in all forms consecutively from the ventral to the dorsal surface. One result of this is that what is in reality pair number 7 in some haptors is designated as pair number 5, and other numbers are thrown off accordingly. A natural system of numbering the hooks, based on their homology, was illustrated for all the common haptor types in my paper, Mueller 1936. This system shows the true homology and displacement of the hooks in different genera, and was advanced prior to Mizelle's method. I therefore believe it should be followed in preference to that proposed by Mizelle.

The present paper describes forms from the Mississippi River, Illinois, New York State, Maryland, and Florida. The Florida and New York material was collected by myself. I am indebted to the Illinois State Natural History Survey for material from Illinois, to the U. S. Bureau of Fisheries for material from Maryland and the Mississippi River, and to Dr. F. F. Bond, of the Johns Hopkins School of Hygiene for further material from Maryland.

A.—**Onchocleidus contortus** sp. nov.

Figs. 15, 42-44

Host: *Aplites salmoides,* on gills, Florida.

Small forms, similar to *O. principalis,* but distal end of gubernaculum with two lateral prongs instead of rounded. Cirrus coiled, with eight turns, 0.03 mm. in straight dimension; accessory piece 0.023 mm. Anchors subequal, 0.039, 0.044 mm. in greatest straight dimension. Bars roughly similar in size, dorsal usually with ornate ends; ventral plain, at times (but not always) with median posterior apron-like projection. Haptor of the *helicis* type. Hooks of medium size, equal, 0.02 mm. in length, pairs 1 to 6 arranged around edge of haptor, directed forward; 7th pair slightly smaller than others, at posterior end, between shafts of anchors, directed backward.

Found on gills of the large mouth bass in association with *Haplocleidus furcatus, Actinocleidus bursatus, A. fusiformis.*

B.—**Onchocleidus perdix** sp. nov.

Figs. 9, 39-41

Host: *Lepomis pallidus,* on gills, Florida.

Small forms, similar to *O. ferox,* but with different cirrus complex. Gubernaculum present, in form of a thin plate with somewhat thickened edge, lying along one wall of the cirrus vestibule, and of relatively indefinite outline, vary-

ing much with the degree of chitinization in different individuals. Cirrus 0.036 mm. long, gubernaculum somewhat shorter. Vagina on right with a short duct leading to the seminal receptacle. Haptor of the *ferox* type. Anchors equal, 0.053 mm. in greatest straight dimension. Bars 0.025 mm. long. Hooks large and thick, as in *ferox*, the 1st pair larger than the others. Found on gills of the bluegill sunfish, in association with *Actinocleidus gracilis*, and *Pterocleidus biramosus*.

C.—**Onchocleidus spiralis** sp. nov.

Fig. 8

Host: Gills of *E. gibbosus*, Florida.

Small forms of the *ferox* type, but differing in the cirrus complex. Cirrus straight, 0.03 mm. long, tubular, having a spiral fin making 5 complete turns, and extending along the distal ⅔ of the organ. Vestibule lightly chitinized to form a cylindrical gubernaculum, through which the cirrus passes in an axial position. Pharynx small, 0.018 mm. in diameter. Haptor of the *ferox* type. Anchors equal, 0.051 mm. in greatest straight measurement. Bars ornate, about 0.023 mm. long. Hooks of pairs 1 to 6 large, on anterior edge of haptor, about 0.032 mm. long, the 1st pair somewhat larger than the others. The 7th pair much smaller and lying between shafts of ventral anchors. Egg oval, 0.043 by 0.035 mm., with terminal filament.

Found on the common sunfish in association with *A. maculatus*, *H. affinis*, and *C. nematocirrus*.

Haplocleidus gen. nov.

Definition: Tetraonchinae, with characters of Onchocleidus in general, but with anchors strikingly unequal, ventral anchors only half as large as the dorsal, but similar in shape. Bars non-articulate. Haptors wedge shaped. Hooks small, with pairs 1 to 6 on anterior edge of haptor, pair 7 at posterior, near shafts of ventral anchors. Vagina on right. Cirrus delicate, of varying form, gubernaculum present, in form of a bipartite chitinized bar with distal end forked. Type species: *Haplocleidus dispar* (Mueller 1936).

When *H. dispar* was originally named it was assigned to the genus Onchocleidus because the difference in the size of the anchors was thought to be of specific value only. Since then two other forms have been found also having such anchors, but differing in the cirrus complex both from *H. dispar*. and from each other. It is clear therefore that a group of species exists, all having this type of haptor, and for these the above genus is erected.

D.—**Haplocleidus affinis** sp. nov.

Figs. 10, 11, 36-38

Host: *E. gibbosus*, Florida, on gills.

Small forms, similar to *H. dispar*, but with conspicuously different cirrus. Cirrus a delicate, spirally coiled tube making 10 turns, greatest straight dimen-

sion 0.05 mm. Gubernaculum a bar with distal end forked, having one short, and one long prong. Degree of chitinization differing markedly in different individuals. Vagina on right, with long narrow sinuous duct leading into seminal receptacle. Dorsal anchors 0.085 mm. in greatest straight dimension; ventral anchors 0.043 mm., both with a very sharp angle between shaft and point, and a pronounced swelling of the shaft adjacent to the angle, the points very straight. Hooks small, 0.019 mm. long, pairs 1 to 6 approximately equal in size. Seventh pair much smaller. Positions as given for the genus.

Found on the gills of the common sunfish in association with *O. spiralis, C. nematocirrus, A. maculatus.*

E.—**Haplocleidus furcatus** sp. nov.

Figs. 12, 13, 34, 35

Host: Gills of *A. salmoides,* Florida.

Small forms, of the *dispar* type, but with different cirrus complex. Cirrus slender, straight, 0.049 mm. long, with a spiral fin making about 6 complete turns along the distal ⅔ of the organ, the proximal turns closer together than the distal. Gubernaculum 0.023 mm. long, of much the same shape as in *dispar,* consisting of a short bar, with two distal equal prongs curving around the lip of the vestibule. Vagina much shorter than in the preceding species, opening on the right. Dorsal anchors 0.069 mm. in greatest straight dimension, the shaft curving into the point without the sharp angle seen in *H. affinis,* and without any swelling of the shaft. Ventral anchors 0.035 mm. long, of the same form as dorsal. Hooks small, arrangement typical of the genus.

Found on the gills of the large mouth bass in association with *O. contortus, A. fusiformis, A. bursatus,* in various localities in Florida.

Pterocleidus gen. nov.

Definition: Tetraonchinae, close to *Onchocleidus,* but with a large flat blade arising from the inner edge of the shaft of the anchors, and following parallel to the point for about ⅔ of its length. Anchors similar and equal. Bars non-articulate. Hooks of medium size, arranged as in *Onchocleidus.* Vagina on right. The wall of the cirrus vestibule may or may not be chitinized to form a gubernaculum. Type species *P. acer* (Mueller 1936).

When *acer* was first described it was taken to be merely a species of the genus *Onchocleidus.* Since then two more species have been found with anchors of the same character, but with distinctive features which set them apart from each other. Mizelle, 1936, described *Onchocleidus acuminatus,* which is of this type and is therefore removed to the new genus as *P. acuminatus* (Mizelle). Another form has been found on Florida fishes, description of which follows:

F.—**Pterocleidus biramosus** sp. nov.

Figs. 14, 32, 33

Host: *Lepomis pallidus,* Florida.

Small forms, similar to *P. acer,* but cirrus of different character, consisting of a delicate tube, 0.034 mm. long, distally provided with a narrow delicate fin

passing spirally around the organ for four complete turns. Wall of vestibule delicately chitinized and supporting the lip of the pore. Anchors equal 0.043 mm. in greatest straight dimension, the shaft somewhat swollen above the origin of the blade. Bars equal, 0.025 mm. long. Hooks medium sized, arranged as in *acer*, first pair somewhat larger than remainder, 7th pair small and lying near shafts of ventral anchors. Pharynx 0.014 mm. in diameter. This form differs from *P. acer* in having a much narrower fin on the cirrus, confined to the distal tip of the same, whereas in *acer* the fin is very large and extends the length of the organ. *Acer* moreover has no gubernaculum. In *P. acuminatus* the cirrus has the form of a spiral tube with 6 turns, and a gubernaculum is present but of different form from that of *P. biramosus*.

Found on the gills of the bluegill, in association with *O. perdix*, *A. gracilis*.

Actinocleidus gen. nov.

Definition: Tetraonchinae; with haptor discoidal, bars articulate, the anterior bar bent into the form of a V, the posterior either V-shaped, or in the form of a flat plate. Anchors equal, all directed ventrad; 14 hooks arranged around edge of the haptor, except for pairs 1 and 7, which may lie centrally. Vagina on left. Cirrus usually rugged, in form of a tapering chitinous tube of large diameter, and provided with a well chitinized accessory piece lying mostly free in the vestibule, parallel to the cirrus, to which it may be articulated at the proximal end. Type species: *A. oculatus* (Mueller 1934).

The members of this genus were originally placed in the genus *Cleidodiscus*. The latter, however, is now reserved for forms generally similar, but with wedge shaped haptor and non-articulate bars. Species falling in the new genus are: *A. fusiformis* (Mueller 1934), *A. bursatus* (Mueller 1936), *A. incisor* (Mizelle 1934), *A. articularis* (Mizelle 1936), and several species described herewith.

G.—**Actinocleidus gracilis** sp. nov.
Figs. 17, 26-28

Host: *Lepomis pallidus*, Florida.

Small forms, similar to *oculatus*, but cirrus consisting of a strongly tapered tube, with wide base, and very pointed extremity, 0.047 mm. long. Accessory piece sigmoid 0.034 mm. long, heavy, with pointed distal extremity, and midway a large triangular muscle attachment. Anchors equal, greatest straight dimension 0.031 mm. Anterior bar longer than posterior, but both of equal width. Hooks arranged as in *oculatus*.

Found on gills of the bluegill in association with *O. perdix*, and *P. biramosus*.

H.—**Actinocleidus maculatus** sp. nov.
Figs. 16, 29-31

Host: *E. gibbosus*, Florida.

Larger than the preceding form, but generally similar. Cirrus relatively wide, sigmoid, tapering slightly. Base broad, distal tip thin walled, somewhat

expanded and folded; greatest straight dimension 0.053 mm. Accessory piece heavy, forked proximally, and saddling the cirrus, distally flattened and curving toward cirrus, greatest dimension 0.035 mm. Bars as in preceding species, but larger, and instead of being equal in width, the posterior is wider, with laterally extended edges. Anchors equal, 0.039 mm. in greatest dimension, with hollow shafts. This species differs markedly from the foregoing in size, in the form of the cirrus and accessory piece, and in having hollow anchors. Both forms differ in the cirrus complex from either *A. oculatus* (Mueller 1934), or *A. articularis* (Mizelle 1936). *A. articularis* and *A. maculatus* both have hollow anchors. *A. gracilis* and *A. oculatus* both have solid anchors. The vagina of this species opens on the left, with the vulva heavily chitinized and conspicuous.

Found on the common sunfish in association with *H. affinis, O. spiralis, C. nematocirrus.*

Genus *Cleidodiscus*

After separating off the genus Actinocleidus for forms mentioned above, the genus Cleidodiscus, type *C. robustus,* remains for those originally included in it, which have a wedge shaped haptor, anchors equal, bars non-articulate, 14 hooks, a well developed accessory piece in the cirrus complex, and vagina opening on the left.

I.—**Cleidodiscus nematocirrus** sp. nov.

Figs. 1, 2, 51-53

Host: *E. gibbosus,* Florida.

Forms of moderate size, about 0.555 mm. long by 0.185 mm. wide, with haptor wedge shaped, well set off from body. Bars non-articulate, subequal, about 0.025 mm. long. Anchors equal, 0.029 mm. in greatest dimension, with hollow shafts. Hooks 0.021 mm. long, arranged as in *C. robustus,* with first pair on ventral anterior edge of haptor, pairs 2-6 around lateral edges, pair 7 between shafts of anchors. Cirrus long and slender, very peculiar (figure 1). A well chitinized accessory piece present, articulating with base of cirrus. At its distal end the accessory piece curves around the cirrus to form a guide, and at this point is provided with a fin for muscle attachment. Accessory piece about 0.044 mm. long; cirrus, following the curves, at least 0.26 mm. long. Vagina opens on the left ventral edge, a very short distance behind the cirrus. It is long and very much convoluted. Its wall becomes heavily chitinized just before joining the seminal receptacle. The pharynx is large and prominent, about 0.053 mm. in diameter. Four eyes present, the posterior pair larger, and farther apart than the anterior.

Glands have been reported on the haptor of a great many of the Gyrodactyloid trematodes, and may be observed at the base of the anchors in most of the species described in this paper. In the present form, however, they are unusually large and prominent, four large pear-shaped glands occupying much of the volume of the haptor, with their ducts lying close to the shafts of the anchors. Since the anchors are hollow in this form, it appears possible, though it was not certainly verified, that they may serve to inject this secretion into

the tissue of the host, perhaps aiding in attachment, or possibly dissolving away epithelial cells which are utilized as food.

Found on the common sunfish, in association with *A. maculatus, H. affinis, O. spiralis.*

J.—**Cleidodiscus mirabilis** sp. nov.

Figs. 6, 7, 47-50

Host: *Leptops olivaris,* Mississippi River.

Large forms, close to *C. floridanus* and *C. pricei,* as much as 1.3 mm. long, and about 0.185 mm. wide. Haptor wedge shaped, well set off from body. Bars about equal in size, but of different design (figs. 49, 50), about 0.089 mm. long. Anchors equal, about 0.073 mm. in greatest dimension, shafts solid. General plan of haptor as in *C. floridanus,* with hooks having a similar distribution, first pair median, ventral, anterior, pairs 2-6 lateral, pair 7 median posterior. The cirrus apparently consists of a very delicate tube of large diameter, expanded widely at its distal end, and much folded, with irregular margins. Greatest dimension 0.107 mm. The accessory piece is well chitinized, 0.089 mm. long, rod-like proximally, but distally divided to form a blunt knob, a blade terminating in two recurved hooks, and a flat delicate leaflike portion which loses itself among the folds of the lip of the cirrus.

Found in pure infections on gills of the mud cat.

K.—**Cleidodiscus stentor** sp. nov.

Figs. 3-5, 45, 46

Host: *Ambloplites rupestris,* Constantia, N. Y.

Forms of moderate size, about 0.6 mm. long, with wedge shaped haptor. Anchors equal, 0.05 mm. in greatest dimension. Bars ornate in outline, about 0.035 mm. long. Hooks of pairs 1-6 equal, 0.019 mm. long, arranged around anterior edge of haptor; 7th pair smaller, and lying between shafts of ventral anchors. Cirrus a thin walled tube of narrow diameter, expanding trumpet-like toward the distal end, about 0.08 mm. long. Accompanied by a flexible, somewhat grooved accessory piece about 0.05 mm. long. Vagina large, on left, having soft folded walls in relaxed condition, but at times tightly constricted at outer end to close off a pear-shaped seminal receptacle. The pharynx is relatively small, 0.035 mm. in diameter. The anterior eyes smaller than the posterior, both equally spaced.

Found in pure infections on the gills of the rock bass.

L.—**Gyrodactylus stegurus** sp. nov.

Figs. 18-20

Host: *Fundulus diaphanus,* Constantia, N. Y.

Small forms, distinguished from other species of the genus by the ventral bar. Length over all about 0.31 mm., width 0.075 mm. Diameter of haptor 0.071 mm. Length of anchors 0.047 mm. Ventral bar 0.021 mm. wide, with

antero-lateral lobes, and with a triangular posterior apron bearing longitudinal striations. Although these parts are larger than in the following species, *G. stephanus*, the striations are closer together, a clear indication of the separation of the two forms. Furthermore, the anchor roots of this form are shorter than in the following. They curve inward somewhat over the lobate ends of the ventral bar. Hooks 0.026 mm. long. Pharynx about 0.053 mm. in diameter, much larger, but of the same form, as in the following species. Cirrus about 0.018 mm. in diameter, with a large spine, and 8 hooklets.

Found in association with *"Ancyrocephalus" angularis* on gills of the fresh water killifish.

M.—**Gyrodactylus stephanus** sp. nov.

Figs. 21-25

Host: *Fundulus heterocleitus*, Baltimore, Md.

Smaller than the preceding, entire body length about 0.2 mm., width 0.071 mm., with differences in the ventral bar. Diameter of haptor 0.053 mm. Anchors 0.039 mm. in greatest length. Points 0.015 mm. Hooks 0.023 mm. long. Ventral bar about 0.019 mm. wide, with posterior triangular prolongation, with striations farther apart than in preceding species. Lateral lobes of bar of different shape from those of *stegurus*. Over the ends of these the roots of the anchors are strongly curved. Pharynx spheroidal, compressed antero-posteriorly, and equatorially divided into a smaller anterior and larger posterior portion, about 0.025 mm. in greatest diameter. The cirrus appears to have about 8 small hooks, and a large spine.

Found in pure infections on the gills of the brackish water killifish.

New Distribution Records

The following records give new localities for species previously described.

Cleidodiscus pricei: on *Ameiurus nebulosus*, Oneida Lake, N. Y.
Cleidodiscus capax: on *Pomoxis sparoides*, Lakeland, Md., Oneida Lake, N. Y.
Onchocleidus ferox: on *Eupomotis gibbosus*, Oneida Lake, N. Y.
Onchocleidus mimus: on *Lepibema chrysops*, Oneida Lake, N. Y.
Actinocleidus bursatus: on *Aplites salmoides*, Peace River, Fla.
Actinocleidus fusiformis: on *Aplites salmoides*, Peace River, Fla.

Some Features of the Incidence of the Gyrodactyloidea on North American Fishes

Enough is now known to indicate some of the outstanding features of the distribution and host selection of these trematodes on this continent. As indicated above, 53 species have now been reported from fishes of this country. Of these, only 3 species are forms also common to Europe: *Tetraonchus monenteron*, found on the pike, *Esox lucius*, in both countries; *Dactylogyrus anchoratus*, a parasite of the goldfish in this country, also widely distributed on cyprinids in Europe; and *Gyrodactylus elegans*, a cosmopolitan parasite of trout.

Among the 53 species, 7 are of the genus Gyrodactylus, and these species have been reported on trout, goldfish, the killifishes, the mud minnow, the black bullhead, and common sucker. The genus Gyrodactylus seems usually to live on the body surface of the host, rarely on the gills. *G. elegans* on trout, and *G. spathulatus* on the sucker, are found only on the body surface and fins, the gills being free. *G. stegurus* and *stephanus*, parasites of killifishes, however, may occur on the gills.

Of the two native species of Dactylogyrus, one, *D. anchoratus*, is cosmopolitan on cyprinids, and is found in this country on the gills of goldfish. The other, *D. extensus*, found on the gills of the carp in Oneida Lake, has not been reported outside of this country.

The remaining 44 forms are all Tetraonchinae and occur on the gills of their hosts. They have been variously placed in a number of genera, but the exact number or limits of these genera are not understood as yet. Eleven species exhibit a host selection as follows: Two closely related forms of the genus Urocleidus occur on the perch and pike perch. *Tetraonchus monenteron* occurs only on the pike, *Esox lucius*, and has never been found on *Esox reticulatus*. To judge from material received from Ohio, however, it appears that the latter may carry *Onchocleidus mimus*, ordinarily a parasite of the silver bass, *Lepibema chrysops*. Three interrelated species occur on silurids: *Cleidodiscus pricei*, on *Ameiurus natalis*, and *A. nebulosus; C. floridanus*, on *Ictalurus punctatus;* and *C. mirabilis*, on the mud cat, *Leptops olivaris*. Two peculiar forms have been found on the striped bass, *Roccus lineatus*, in Florida: *Lepidotes collinsi*, and *Aristocleidus hastatus*. The genus Lepidotes had previously been reported only from Australia. One form, *Onchocleidus interruptus*, occurs on the yellow bass *(Morone interrupta)*. Another form, of uncertain relationships, *"Ancyrocephalus" angularis*, occurs on the gills of *Fundulus diaphanus*.

The remaining 33 species occur on the Centrarchidae. It is clear that in this family of fishes the Tetraonchinae find their most favorable hosts, and have here undergone their most extensive evolution and speciation. Of the 33 species known from these fishes, the host selection is as follows:

Large Mouth Bass *(Aplites salmoides)*,—4 species.
Actinocleidus bursatus, Haplocleidus furcatus, Onchocleidus helicis, O. contortus.

Small mouth bass *(Micropterus dolomieu)*,—3 species.
Leptocleidus megalonchus, Tetracleidus banghami, Actinocleidus fusiformis.

Kentucky bass *(Micropterus pseudaplites)*,—1 species.
Onchocleidus principalis.

Rock Bass *(Ambloplites rupestris)*,—1 species.
Cleidodiscus stentor.

Crappies *(Pomoxis sparoides, annularis)*,—5 species.
Onchocleidus formosus, Cleidodiscus vancleavei, C. longus, C. uniformis, C. capax. Because of possible confusion in the determination of the host, the exact host selection of some of these species is not known.

Long eared sunfish *(Xenotis megalotis)*,—4 species.
Cleidodiscus bedardi, Actinocleidus articularis, Onchocleidus distinctus, O. acuminatus.

Bluegill *(Lepomis pallidus)*,—6 species.
Actinocleidus gracilis, Cleidodiscus incisor, C. robustus, Onchocleidus mucronatus, O. perdix, Pterocleidus biramosus.
Common sunfish *(Eupomotis gibbosus)*,—10 species.
Cleidodiscus robustus, C. nematocirrus, Actinocleidus oculatus, A. maculatus, Haplocleidus affinis, H. dispar, Onchocleidus spiralis, O. similis, O. ferox, Pterocleidus acer.

Certain fishes appear to possess a complete immunity from these parasites. Thus, the gars, *Lepisosteus osseus,* and *platostomus,* have been examined in numbers from the east, south, and middle west, but apparently never carry these worms. Numerous Lota have been examined but none found infected. Although too few specimens have been examined to permit definite conclusions as yet, it appears that the war-mouth bass *(Chaenobryttus)* possesses a similar immunity, and likewise the spoonbill *(Polyodon),* the shovel nose sturgeon *(Scaphirhynchus),* the carp suckers *(Carpiodes),* the fallfishes *(Semotilus, Leucosomus),* and the eel *(Anguilla).*

Tetraonchinae do not occur on trout, suckers, or cyprinids, but the genus Gyrodactylus does, occurring over the entire body surface. As a less common parasite of cyprinids, the genus Dactylogyrus may also be present, but limited to the gills only.

The Centrarchidae, Siluridae (as a rule), Percidae and Esocidae do not carry Gyrodactylus or Dactylogyrus but are infected with the Tetraonchinae, which occur on the gills only, and never on the external body surfaces.

Since in the north it is the experience of fish culturists that epidemics of gyrodactyloid parasites are more common during warm weather, it might seem that the group would flourish to a greater extent on southern fishes than in northern waters. Collections in Florida, however, do not show this to be the case. Many fishes there have only light infections, if any, and in general the frequency and abundance of these parasites is no greater in the south than in the north. As a possible explanation of this it may be advanced that more favorable conditions for reproduction of the parasites in warm regions are offset by an increased immunity on the part of the host.

Since the greatest variety of fish forms occurs in the Mississippi Valley and eastern waters, and since representatives of most families in these regions have been examined, it is probable that the main species and genera of the Gyrodactyloidea occurring in this country are now known. Since the fishes of the western coast are mainly trout and other salmonids, *Gyrodactylus elegans,* a parasite of trout, and extensively reported from that region, is probably the most important representative of the group occurring there. However, it seems likely that examination of the body surface of the cyprinids, suckers, and smaller fishes (a location which to date has been largely neglected) will bring to light further species of the genus Gyrodactylus. Further species of Tetraonchinae will also doubtless be found on fishes now known to serve as hosts to that subfamily, but it appears that most of the genera have already been recognized, since the newer species readily fall into previously described structural types.

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EXPLANATION OF PLATES

To facilitate location of figures, all drawings belonging to the same species have been given a letter.

Scale with figs. 3, and 45 applies to figs. 3-5, 45, 46.
Scale with figs. 6, 7, 47, applies to 6, 7, 47-50.
Scale with figs. 1, 34, applies to all others.

A.—*Onchocleidus contortus:* 15, Cirrus and accessory piece. 42, Ventral anchor. 43, Ventral, 44, dorsal bars. Both outlines indicated by dotted line in 43 occur in different individuals.

B.—*Onchocleidus perdix:* 9, Cirrus and gubernaculum. 39, 40, Anchors. 41, One of bars (both similar).

C.—*Onchocleidus spiralis:* 8, Cirrus and gubernaculum of two specimens.

D.—*Haplocleidus affinis:* 10, Cirrus and accessory piece. 11, Vagina. 36, Dorsal, 37, ventral anchor. 38, Ventral bar.

E.—*Haplocleidus furcatus:* 12, Cirrus and gubernaculum. 13, Vagina. 34, Dorsal, 35, ventral anchor.

F.—*Pterocleidus biramosus:* 14, Cirrus and gubernaculum. 32, Ventral, 33, dorsal anchors and bars.

G.—*Actinocleidus gracilis:* 17, Cirrus and accessory piece. 26, Bars. 27, Anterior 28, posterior anchors.

H.—*Actinocleidus maculatus:* 16, Cirrus and accessory piece. 29, Bars. 30, Posterior, 31, anterior anchors.

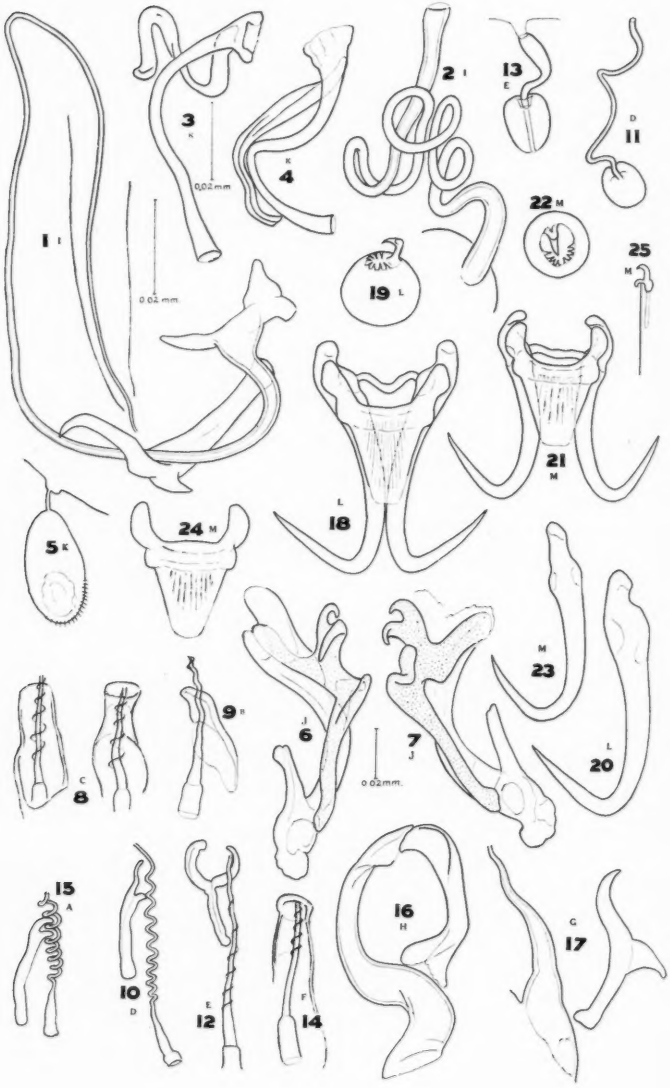
I.—*Cleidodiscus nematocirrus:* 1, Cirrus and accessory piece, filamentous distal end downward. 2, Vagina, distal end uppermost. 51, Dorsal, 52, ventral bars. 53, One of the anchors (all similar).

J.—*Cleidodiscus mirabilis:* 6, 7, Cirrus and accessory piece (latter stippled) in two specimens. 47, 48, Anchors. 49, 50, Bars.

K.—*Cleidodiscus stentor:* 3, 4, Cirrus and accessory piece, distal end downward, two specimens. 5, Vagina. 45, Ventral anchors and bar, also showing seventh pair of hooks. 46, Dorsel bar.

L.—*Gyrodactylus stegurus:* 18, Anchors and bars. 19, Cirrus, side view. 20, Anchor.

M.—*Gyrodactylus stephanus:* 21, Anchors and bars. 22, Cirrus. 23, Anchor. 24, Bar. 25, Hook.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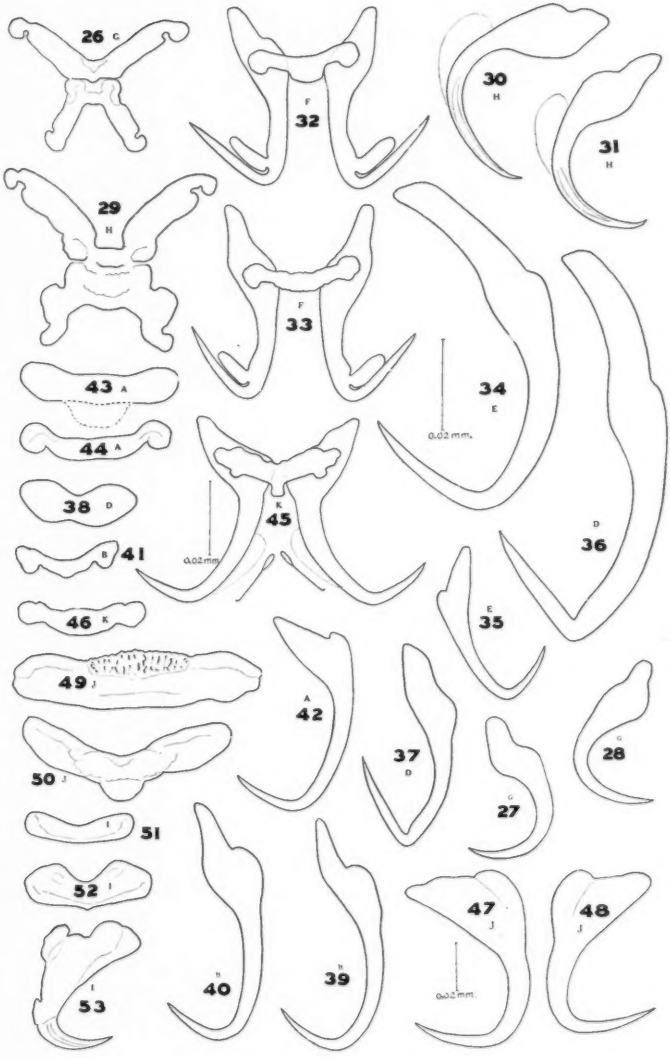
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46 K
35 E
49 J
42 A
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28 G
50 J
27 G
51 I
52 I
47 J
48 J
53 I
40 H
39 H
0.02 mm.

Two New Blind Isopods from Northeastern Oklahoma

H. D. Chase and A. P. Blair

On December 27, 1935, a large new *Caecidotea* was found in a small stream in a cave five miles south of Kansas, Oklahoma. The stream pursues a very narrow and rocky course, and, at this time of year, being nowhere more than two feet wide or eight inches deep, until it emerges upon a bed of guano some fifty feet from the mouth of the cave. It was in this shallow, muddy area that the greatest aggregation of Caecidotea was found, doubtless due to the fact that more organic matter which would serve as food was here available. In this pool were also found great numbers of a new species of white turbellarian, (which is being described by Dr. Libbie Hyman), and numerous larvae of *Eurycea lucifuga* and *Eurycea melanopleura*. In several instances, many of the turbellarians were seen aggregated in one spot, and, in each instance, a dead *Caecidotea* was found upon which the former seemed to be feeding. In the small rocky stream the Isopods and flat-worms were found in diminished numbers, but the *Eurycea* larvae tended to give way to Typhlotriton as the muddy pool was left behind. A number of the specimens of the Isopods and salamander larvae were taken and kept alive for well over a month. The Caecidotea seem to be able to stand considerable temperature changes with no ill effects as the specimens were several times inadvertently left in a hot room until the temperature of the water had risen to a point far above that to which they were accustomed. One of the salamander larva kept with the Isopods was one day observed eating a Caecidotea, but whether it was taken alive remained a question. It has been noticed that many of the Isopods taken have one or both of the terminal appendages missing. Observation seems to indicate that this is due not only to attacks by salamander larvae but to the isopods fighting among themselves. The first walking leg is modified as a formidable offensive weapon and the captive specimens have at several times been seen attacking one another.

The smaller of the new Isopods was found July 12, 1936 in a spring about one-half mile from the cave mentioned above. All specimens taken were found hiding under small stones. They were placed in a jar with two larval *Eurycea melanopleura* from the same spring. One of the larvae immediately seized and swallowed an Isopod, then snapped at another, but got only the terminal appendages or uropoda. It seems quite logical to believe that Isopods furnish an important item of diet for larval salamanders and that the absence of uropoda in many specimens can be, at least in part, explained on this basis.

We have chosen to call the larger Isopod *Caecidotea macropropoda*, and the smaller, *Caecidotea ozarkana*. The description and illustrations of the two species are based on male specimens.

Caecidotea macropropoda sp. nov.

Description: Body 13-17 mm. long; 3 mm. wide. Head 2 mm. wide; about 1 mm. long. Eyes absent. First article of first antenna stouter than and one-half as long as second article; third article equal in length to first article; flagellum of 13-18 articles. First article of second pair of antenna half as long as second article; third article half as long as second article; fourth article as long as first three articles taken together; fifth article as long as first four articles taken together; flagellum composed of 91-123 articles. The maxilliped has a palp of five articles and the mandible a palp of three articles. The segments of the thorax are loosely articulated, the lateral margins not being contiguous. The first, second, sixth, and seventh thoracis segments are longer than the third, fourth and fifth segments. The first two abdominal segments are very narrow. The third segment is elongated, being four-thirds as long as wide. The uropoda are twice as long as the terminal segment. The peduncle and inner branch are equal in length, each being as long as the terminal segment. The outer branch is one-third as long as the inner branch. The propodus of the first pair of legs is very large and has on its inferior margin two long triangular processes and two short ones.

Locality: Cave five miles south of Kansas, Oklahoma.

Caecidotea ozarkana sp. nov.

Description: Body 6-8 mm. long; 1-3 mm. wide. Head as wide as body and about as long as wide. Eyes absent. First article of first antenna stouter than and a little shorter than second article; third article two-thirds as long as second article and not so stout as second article; flagellum of 11 segments. First article of second antenna about equal to second article; third article a little shorter than second article; fourth article equal in length to first three articles taken together; fifth article a little longer than fourth article; flagellum of 60-70 segments. The maxilliped has a palp of five articles and the mandible a palp of three articles. The thoracic segments are loosely articulated. The first and seventh segments are longest. The first two abdominal segments are narrow; the elongated third segment is about three-halves as long as wide. The uropoda are a little longer than the terminal segment. The peduncle and inner branch are equal in length and the outer branch is a little more than half as long as the inner branch. The triangular processes of the propodus, on the first pair of legs, vary from one large one on the distal portion of the inferior margin with spines along the edge, to one large triangular process located distally and two located proximally accompanied by spines along the margin.

Locality: Spring five miles south of Kansas, Oklahoma.

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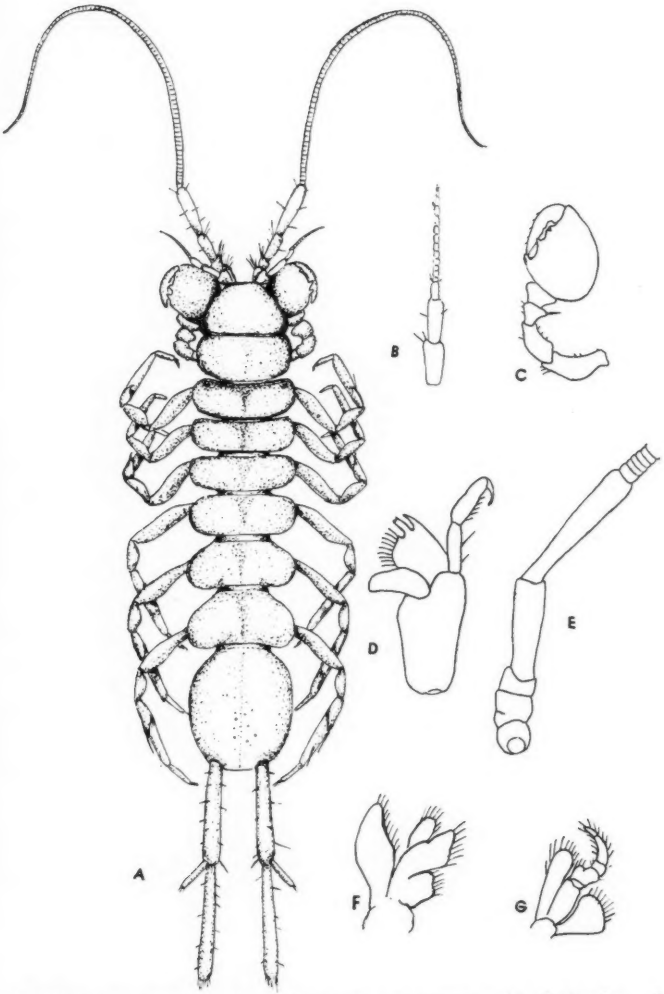
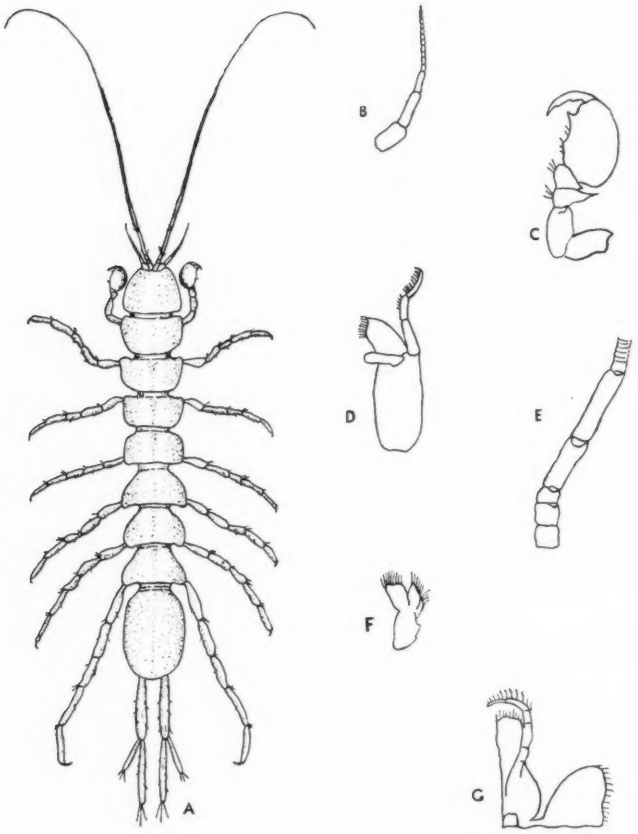
PLATE I



Caecidotea macropropoda. A, adult, x 5; B, first antenna, x 16; C, first leg, x 10; D, mandible, x21; E, proximal portion of second antenna, x 16; F, maxilla, x 13; G, maxilliped, x 10.

PLATE 2



Caecidotea ozarkana. A, adult, x 12; B, first antenna, x 22; C, first leg, x 22; D, mandible, x 28; E, proximal part of second antenna, x 21; F, maxilla, x 21; G, maxilliped, x 21.

The Genera Cyperana and Paluda (Homoptera - Cicadellidae)

Dwight M. DeLong

In an effort to clarify the relationship of a large number of species of leafhoppers formerly included in the genus Thamnotettix, several new genera have been erected and the present treatment is an attempt to establish certain of these species belonging to two genera on the basis of the internal genital characters of the males. The coloration and other characters are also given in the descriptions.

KEY TO GENERA

1 Yellow or orange yellow without black spots on vertex. Male plates with dorsal blunt spine on apical half. Ninth segment terminating in a pair of blade-like processes as long as basal portion of segment----------*Paluda*

1' Yellow, green or tawny, vertex marked with black spots or band on margin. Male plates without a dorsal spine, with segment rounded or angled normally-*Cyperana*

Genus *Cyperana* DeLong

The genus Cyperana Delong was recently described[1,2] to include the common green leafhoppers of the Thamnottetix type which occur in fresh water marshes on Cyperus, other sedges and grasses. They are characterized by having a bluntly angled vertex which is produced but sometimes almost rounded at apex. The elytra are long and narrow with venation as in Thamnotettix. The species are usually some shade of green or yellow with a black band or a row of black spots on the margin of the vertex between the eyes.

The members of this genus occur throughout the United States but the larger number of species are found only in the eastern portion, some occuring as far west as the Rocky Mountains. Heretofore only ten species which apparently belong to this genus have been described or recorded for the North American fauna. Four additional species, all western in distribution, are described in the following pages. Since these species have been somewhat confused because of similar color markings, previous records for distribution cannot be relied upon in some cases. The records included here have been checked for the male genital characters which structures have not been previously illustrated nor used in published treatments of these species. The female characters are quite similar in type and are of value in separating species only in a few cases.

1 Ohio Jour. Sci. 35:217-219, July 1936.

2 Since submitting the manuscript (September 1936) two species, *C. smithi pollicarius* and *C. wanakena* have been described by Ball (Pan Pacific Ent. October 1936). They are not illustrated and can not be definitely placed at this time.

KEY TO SPECIES

1 Tawny or pale brown, longitudinally marked with brownish or reddish stripes, spots on vertex linear in form or forming a band 2
1′ Yellow or green without longitudinal stripes 3
2 (1) Vertex with four linear black spots on margin of vertex ..... *cyperacea*
2′ Vertex with a black band on margin of vertex ..... *vittipennis*
3 (1′) Size 6.5-7 mm. pale yellow with a pair of large black spots at apex and a pair of smaller spots next eyes ..... *straminea*
3′ Size not exceeding 6 mm. usually green or yellowish green 4
4 (3′) Black coloration on margin of vertex forming a band between eyes 5
4′ Black coloration on margin of vertex in form of spots 6
5 (4) Vertex twice as wide between eyes as median length, band rather straight and even. Male plates with apical finger process on inner margin ..... *smithi*
5′ Vertex one-half wider between eyes than median length, band sinuate, uneven, male plates broadly inflated on apical half and strongly convexly rounded to form a blunt apex ..... *montula*
6 (4′) Male plates broadly bluntly rounded at apex, styles decidedly longer than plates obliquely sloping at apex and sharp pointed on outer margin ..... *stylata*
6′ Male plates more pointed at apex styles not decidedly longer than plates 7
7 (6′) Four black spots on margin of vertex but without markings posterior to ocelli 8
7′ Markings on margin of vertex and also posterior to ocelli 9
8 (7) Male plates deeply concavely excavated on inner margin of apical third, styles tapered from base to apex ..... *melanogaster*
8′ Male plates sloping on inner margin, not concavely rounded, styles with a pair of finger-like processes at apex, an inner long one and an outer short one ..... *ciliata*
9 (7′) Male plates without prolonged finger-like processes at apex, oedagus bifid at apex 10
9′ Male plates longer with finger-like processes at apex, oedagus not bifid 11
10 (9) Male oedagus short not greatly enlarged at base, size smaller 3.5-4.5 mm. Known to occur only in western U. S. and Canada ..... *longiseta*
10′ Male oedagus long, large at base, apical two-thirds very slender, larger more than 4.5 mm. Northeastern in distribution ..... *decipiens*
11 (9′) Inner finger process of style long and slender, outer finger process curved outwardly, oedagus tapered on apical half to pointed tip ..... *gesa*
11′ Inner finger process broader, outer process slender curving inwardly together forming a chela, oedagus not narrowed until near apex ..... *eruca*

Cyperana cyperacea (Osborn)

Thamnotettix cyperaceus Osb. Proc. Ia. Acad. Sci. **5**:245, 1898

A tawny species with orange or brownish longitudinal stripes and four black dashes on margin of vertex. Length 5.5-6 mm.

Vertex flat and bluntly angled, one half wider between eyes at base than length at middle.

Color: vertex creamy with four linear spots on margin between eyes. A median narrow stripe extending from apex of vertex to apex of scutellum and a broad one extending from margin of vertex next either eye to basal angle of scutellum, tawny or brownish. Elytra tawny to brown, nervures pale.

Genitalia: Female last ventral segment with lateral angles broadly rounded,

posterior margin slightly narrowly indented either side of a broad, median slightly produced tooth. This median tooth is about one-third the width of segment. A large round area on outer third of segment each side composed of oblique ridges and striae. Male plates rather long and broad, each convexly rounded to blunt apex which bears a rather long incurved finger-like process at its apex. Styles long, broad on basal half, then rather rapidly narrowed to slender apical processes which are produced half the length of style. Oedagus rather small, slightly enlarged at base, apical portion narrowed, produced dorsally and curved anteriorly.

This species occurs on Cyperus in fresh water marshes and is a common species in the northeastern states. Specimens have been examined from New York, Pennsylvania, Ohio, Illinois, Wisconsin and Iowa. It undoubtedly occurs in similar habitats in the intermediate states.

Cyperana vittipennis (Sanders & DeLong)

Thamnotettix vittipennis S. & DeL. Ann. Ent. Soc. Amer. **10**:91, 1917

Resembling cyperacea in form and general appearance but with vertex more rounded and with a black marginal line between the eyes. Length 5.5-6 mm.

Vertex bluntly angled, twice as wide between eyes as length at middle.

Color: Vertex with a black marginal stripe between eyes. A broad tawny band covering disc and extending to eyes, posterior central portion pale. Pronotum tawny to testaceous. Elytra tawny, nervures white margined with brown, appearing striped.

Genitalia: Female last ventral segment with posterior margin slightly emarginate and narrowly notched either side of middle, outer third striated as in cyperacea. Male plates short and broad, convexly rounded on outer margin and strongly sloping on inner margin to form a blunt tooth-like structure at apex. Styles long, sinuately tapered from base and curving outwardly to form blunt apices, pointed on outer margin. Plates decidedly longer than styles. Oedagus slender, slightly enlarged at base, normally directed dorsally, curved slightly caudally at middle.

Known only from the four type specimens collected at Trout Lake and Ladysmith, Wisconsin in August and September 1916 by the writer. No other records have been published and no additional specimens have been available for study.

Cyperana straminea (Sanders & DeLong)

Thamnotettix stramineus S. & DeL. Ann. Ent. Soc. Amer. **10**:90, 1917

A large yellow species with black dashes on margin of vertex. Length 6.5-7 mm.

Vertex broad and bluntly angled, almost twice as broad as median length.

Color yellow sometimes tinted with orange, with four transverse black

spots on margin of vertex. The spots either side the apex of vertex are large and those next the eyes are small.

Genitalia: Female last ventral segment with outer angles forming broadly rounding lobes between which the posterior margin is shallowly concavely rounded. The outer third of segment on either side black with prominent oblique ridges and striae. Male plates short, gradually narrowed on inner margin and convexly rounded on outer to form a prominent pointed projection at apex. Styles long and slender, tapering and slightly constricted just before bluntly pointed apex.

This is also a marsh species but is restricted to higher altitudes or more northern areas. The known distribution includes the type series from localities in northern Wisconsin, as well as specimens from Cranberry Lake, N. Y. (Osborn) and Gillette, Pennsylvania, August 30, 1922 (Sanders and DeLong.

Cyperana melanogaster (Provancher)

Jassus melanogaster Prov. Nat. Can. **4**:387, 1872

A greenish or yellowish species with four large black spots in a row on margin of vertex. Length 5-5.5 mm.

Vertex bluntly angled, one-half wider between eyes than length at middle.

Color yellow to green but always conspicuously marked by a row of four large black spots in a row on margin of vertex between the eyes. The spots are about equidistant, one on either side of blunt apex and one next either eye. The elytra often appear darker or may be orange.

Genitalia: Female last ventral segment with posterior margin sinuate and broadly, shallowly emarginate. Male plates abruptly concavely narrowed on inner margin to produce bluntly pointed apices. Styles long and slender, narrowed near base and produced into long tapering processes with bluntly pointed apices. Oedagus long, slender and usually directed dorsally. Basal portion a little thicker and with anterior process, apical portion slender and pointed at tip.

This is the most common marsh species of this genus and occurs abundantly throughout the eastern United States from Maine to South Dakota and south to the Ohio River. It is not so abundant south of the Ohio River but has been taken in North Carolina and Tennessee. It is also common in Quebec and Ontario.

Cyperana ciliata (Osborn)

Thamnotettix ciliatus Osb. Proc. Ia. Acad. Sci. **5**:244, 1898

Similar to *melanogaster* in form and coloration but with black spots on vertex smaller and with distinct genitalia. Length 5-5.5 mm.

Vertex blunt, scarcely angled almost twice as wide between eyes at base as median length.

Color green tinged with yellow. Vertex pale yellow with four small round black spots in a row on margin of vertex. Ocelli black, above and between the two spots on either side. Pronotum, scutellum and elytra usually green.

Genitalia: Female last ventral segment with lateral angles rounding to posterior margin which is broadly shallowly emarginate. Male plates short and broad, strongly convexly rounded on outer margin and strongly sloping on inner margin to a blunt apex with a slight tooth like projection. Oedagus broad at base, constricted and produced dorsally and anteriorly as a wide blade-like structure which is pointed at apex.

A species occurring on sedges in fresh water marshes. Specimens have been examined and characters checked from Maine; Madison, Wisconsin; Lincoln, Nebraska; and Sioux City, Iowa. It is also reported for Colorado but these specimens have not been available for checking. A large series of specimens in the writer's collection is from craters of the Moon Idaho and Tahoe Lake, California.

Cyperana smithi (Van Duzee)

Thamnotettix smithi V. D. Can. Ent. **24**:266, 1892

Green with a broadly rounded vertex and a broad black band on margin of vertex between the eyes. Length 5 mm.

Vertex broadly rounded well produced but almost parallel margined, twice as wide between eyes at base as median length.

Color green tinged with yellow, vertex with a broad black band on the margin between the eyes. Elytra appearing darker greenish, apices usually smoky.

Genitalia: Female last ventral segment with lateral angles broadly rounded. Posterior margin slightly emarginate either side of a broad slightly produced tooth at middle which is produced almost as far as the rounded lateral angles. Male plates short, sides convexly rounded to blunt apex with a short blunt tooth like projection. Styles rather long narrowed at about one third their length and produced to form a spur-like tooth on outer margin and an elongated rather broad finger-like process on inner margin which is blunt at apex. Oedagus rather short, enlarged at base, narrowed at about half its length to form a slender apical process which is directed dorsally.

This species ocurs on *Spartina michauxiana* in fresh water marshes and is found only in rather northern areas. Records are at hand and specimens have been examined from New Jersey; Connecticut; Presque Isle, Pennsylvania; northern Illinois (Princeton); Iowa and Wisconsin.

Cyperana decipiens (Provancher)

Thamnotettix decipiens Prov. Pet. Faune. Ent. Can. **3**:285, 1890

Resembling melanogaster in form and color but with two outer spots above margin and posterior to ocelli. Length 4.5-5 mm.

Vertex blunt and rounded at apex, almost twice as wide between eyes at base as length at middle.

Color: Vertex yellow tinged with green, with two large round black spots on margin of vertex, one either side of blunt apex. A black spot next either

eye above margin and posterior to ocellus. Pronotum and scutellum usually green and darker. Elytra appearing darker green with veins paler.

Genitalia: Female last ventral segment with lateral angles rather well produced between which the posterior margin is sinuately concavely emarginate more than one-third the distance to base. At the apex of this emargination is a very short blunt white tooth. Male plates rather broad and short convexly rounded to blunt apices. Styles long and narrow inner margin produced into a long curved finger-like process, outer margin with a very short spur only. Oedagus large at base rapidly constricted to a very slender apical portion which is long and curves dorsally and anteriorly and is bifid at apex. A large black bifurcate spine is on the dorsal caudal portion of pygofer.

This species was described from Quebec, Canada and has since been recorded for Maine, New York, Utah and British Columbia. Records are also at hand from Wisconsin; Kane, Pennsylvania; Pingree Park, Colorado; Shoshone Basin and Stanley Basin, Idaho; Everett Lake, Washington; and Slave Lake, Alberta. These specimens have been checked for genital characters.

Cyperana stylata sp. nov.

Resembling an orange colored specimen of *melanogaster* but with distinct genitalia. Length 5.5-6 mm.

Vertex bluntly angled, almost twice as wide between eyes at base as length at middle.

Color orange yellow to sordid green washed with orange. The four black spots on margin of vertex variable in size and form but usually more elongate laterally. The median pair always larger than those next the eyes. Elytra often orange or sordid green at base, apex hyaline with veins orange.

Genitalia: Female last ventral segment almost truncate, posterior margin slightly indented either side of broad slightly produced median lobe. Male plates short and broad, roundedly expanded toward apex which is blunt and rounded and bears a minute black tooth at apex. Styles long, tapering from base to sharp pointed, outwardly directed apices. Oedagus rather broad at base abruptly and concavely narrowed to a rather long slender apical process which is normally directed dorsally.

Described from a series of 42 male and 34 female specimens. Holotype —male; New Port, Idaho, August 8, 1926, R. W. Haegele, collector. Allotype—female; Stanley Basin, Idaho, July 19, 1930, D. M. DeLong, collector; Paratypes—two female and one male, Mackey, Idaho, July 7, 1926, R. W. Haegele; ten females and twenty males, Fish Lake, Utah, September 2, 1930. D. M. DeLong collector; three males, Stanley Basin, Idaho, August 3, 1930; two females and two males, Galena Summit, Idaho, August 3, 1930; one female, Tamarack, Idaho, July 26, 1926; one male, Stanley, Idaho, July 10, 1926, R. W. Haegele; 14 male and 18 female specimens, Slave Lake, Alberta, Aug. 14-17, 1924, Bryant; all in collection of the author.

Cyperana gesa sp. nov.

In general appearance resembling melanogaster but differing in color markings and with distinct genitalia. Length 5.5-6 mm.

Vertex bluntly angled almost rounded, almost twice as wide between eyes at base as length at middle.

Color: Bright yellow tinted with orange and shading to dull green. Vertex with a pair of large marginal spots flattened ventrally and convexly rounded above on either side of apex of vertex. A much smaller one next either eye on marginal line. A very small spot just posterior to each ocellus and a pair of dots just back of apex at anterior end of impressed basal line. Sutures separating frons, clypeus and genae, and antennal pits, black. Pronotum, scutellum and elytra sordid green tinged with yellow.

Genitalia: Female last ventral segment with lateral angles broadly rounded to posterior margin which is broadly, shallowly emarginate. Areas at either side of segment with oblique striae. Male plates rather short and broad, abruptly narrowed at apex to short finger-like process near inner margin. Styles long and rather narrow except at base. The inner margin is produced into a long narrow finger-like process one-third the length of style. A shorter process is produced on outer margin. Oedagus long, recurved on itself. Enlarged at base with apical portion blade-like, gradually narrowed to pointed tip and normally curving anteriorly.

Described from one male and two female specimens.

Holotype—male; Redfish Lake, Idaho; August 3, 1930; collected by the writer. Allotype—female; Tahoe Lake, California; August 6, 1930; same collector. Paratype—female; same data.

Type specimens in author's collection.

Cyperana eruca sp. nov.

Resembling gesa in form and coloration but with more strongly produced vertex which is more heavily marked and with genitalia distinct. Length 5-5.5 mm.

Vertex bluntly angled, more than two thirds wider between eyes at base than length at middle.

Color: Vertex yellow, with four quadrate black spots on margin of vertex, the central pair are much larger than those next the eyes. A small round black spot just posterior to ocellus and next to eyes and a pair of small dots just above apex. Sutures of face, antennal pits and venter black. Pronotum and elytra sordid green, veins of elytra orange or pale. Scutellum yellowish.

Genitalia: Female last ventral segment with posterior margin truncate. Segment without striae. Male plates short and broad, strongly convexly rounded on inner margin to rather abruptly pointed apex. Styles long and narrow, the inner margin convexly rounded to form a long rather heavy finger-like process. This together with the one on the outer margin form a chela-like structure. Oedagus enlarged at base then narrowed into a long blade-like

structure which is curved anteriorly and rather abruptly narrowed near apex to an upturned blunt tip.

Described from a series of seven male and eight female specimens. Holotype—male; Boise, Idaho; July 11, 1930, D. M. DeLong collector. Allotype—female; Alturas Lake, Idaho; July 19, 1930. Paratype—male and female; same date; male and female; Brookings, South Dakota; Sept 9 and October 15 respectively, 1920; H. C. Severin collector; male and female; Yosemite Park, California; August 10, 1930; D. M. DeLong collector; all in author's collection. Four female and two male; Yosemite California; June 28, 1931; E. D. Ball collector and one male Weed, California; June 27, 1934; E. D. Ball collector; all in Ball collection.

Cyperana montula sp. nov.

Resembling eruca in general appearance but with distinct coloration and genitalia. Length 5-6 mm.

Vertex bluntly angled more than one-half wider between eyes than length at middle.

Color: Yellow marked with sordid green and black. Vertex yellow with the four black spots on margin fused to form a rather broad, conspicuous sinuate band between eyes which is sometimes interrupted at middle. A conspicuous black spot is posterior to each ocellus and a proximal pair of black lines is usually on disc. Pronotum sordid green. Elytra dull greenish subhyaline, veins pale heavily bordered with brown.

Genitalia: Female last ventral segment with posterior angles broadly rounded, posterior margin narrowly shallowly emarginate either side of a broad slightly produced rounded median lobe. Outer portions of segment with heavy oblique striae, male short and broad, the apical half roundedly inflated and convexly roundedly narrowed on both inner and outer margins to form a bluntly jointed apex. Styles long, gradually tapered from base to a pointed incurved apex. Oedagus erect, broad on basal half, rather abruptly narrowed to blade-like portion on apical half which is curved anteriorly and gradually narrowed to pointed apex. Basal end also tapered and pointed.

Described from a series of four male and two female specimens. Holotype—male; Estes Park, Colorado; August 25, 1920; H. C. Severin collector. Allotype—female; same locality; August 27, 1920; H. C. Severin collector. Paratypes—three males; same data; one female; Pingree Park, Colorado; August 20, 1929; J. G. Sanders collector; all specimens in author's collection.

Cyperana longiseta (Van Duzee)

Thamnotettix longiseta V. D. Can. Ent. **24**:266, 1892

A species resembling melanogaster in coloration but with a broad blunt head and a pair of tiny spots back of ocelli as well as the four on the anterior margin of vertex. Length 3.5-4.5 mm.

Vertex bluntly angled, two-fifths wider between eyes than length at middle.

Color dull green tinged with yellow. Vertex with a row of four round black spots on margin of vertex and a very small one just posterior to each ocellus. Elytra appearing darker, veins pale.

Genitalia: Female last ventral segment sinuate and almost truncate, with posterior margin slightly concave. Male plates short and broad, strongly convexly rounded on outer and inner margins to form a bluntly pointed apex. Styles narrowed gradually from base to form a long finger-like process on inner margin which is strongly curved outwardly and a much shorter process on outer margin, about one-third the length of the inner process. Oedagus only slightly enlarged at base curved dorsally and anteriorly about as far as base, apex bifid.

This is the common western species of the genus occurring on marsh grasses and sedges throughout the states of the northwest.

Specimens are at hand from Colorado; Craters of the Moon, American Falls, Stanley Basin, Blackfoot, and Red Fish Lake, Idaho; Colfax, Lodi and Donner Lake, California; and it has been reported from Iowa, but no specimens have been examined which are of this species.

Paluda gen. nov.

Related to Cyperana but differing by the male plates bearing a dorsal blunt tooth on the posterior portion and the apices of the ninth segment (pygofers) terminating in blade-like structures which are produced the length of the segment and directed dorsally and caudally. The oedagus is also different in type, having a broad basal structure and a short narrow apical process. The absence of black spots on the margin of the vertex also separates this genus from Cyperana.

Type of genus *Thamnotettix placidus* Osborn.

Only one species which is strikingly different in structural and color characters is placed in this genus. It is a common inhabitant of fresh water marshes, but is restricted to northern areas.

Paluda placida (Osborn)

Thamnotettix placidus Osb. Twentieth Rept. N. Y. St. Ent., p. 536, 1905
Thamnotettix mellus S. & DeL. Ann. Ent. Soc. Amer. **10**:91,1917

An orange yellow species without dark markings. Length 5 mm.

Vertex broadly rounded, almost twice as wide between eyes as length at middle.

Color: Orange yellow without definite markings. Elytra subhyaline veins orange yellow.

Genitalia: Female last ventral segment with rather prominent lateral angles, between which the posterior margin is rather broadly excavated about one-third the distance to base. The sides of the excavated portion are slightly convex, the apex is rather broad and there is a slightly produced, rounded

tooth at center. Male plates rather long, gradually, evenly narrowed to bluntly angled apices. Styles sinuately, gradually narrowed from a broad base to outwardly directed, bluntly pointed apices. Oedagus broad on basal two-thirds then rapidly narrowed to a slender apical third which is directed dorsally. Apical portion of pygofers narrowed into blade-like structures which are strongly produced caudally and dorsally the length of the pygofer proper.

This species is north eastern in its distribution and apparently is confined to the area occupied by the northern conifer forest. It has been recorded only for Maine, New York, Wisconsin and New Brunswick, Canada. Specimens in the author's collection and the Osborn collection have been examined from these localities. One specimen is also at hand which was collected by the writer at Redfish Lake, Idaho, August 3, 1930. This is the only western record I have seen and extends the range considerably over previous known records.

Although the type specimens of *Thamnotettix mellus* S. & DeL. are pale in color and appear more narrow it has been impossible to find significant differences in the genital characters of this species and placida. It therefore seems advisable to place this as a synonym of the former species.

Ohio State University,
Columbus, Ohio.

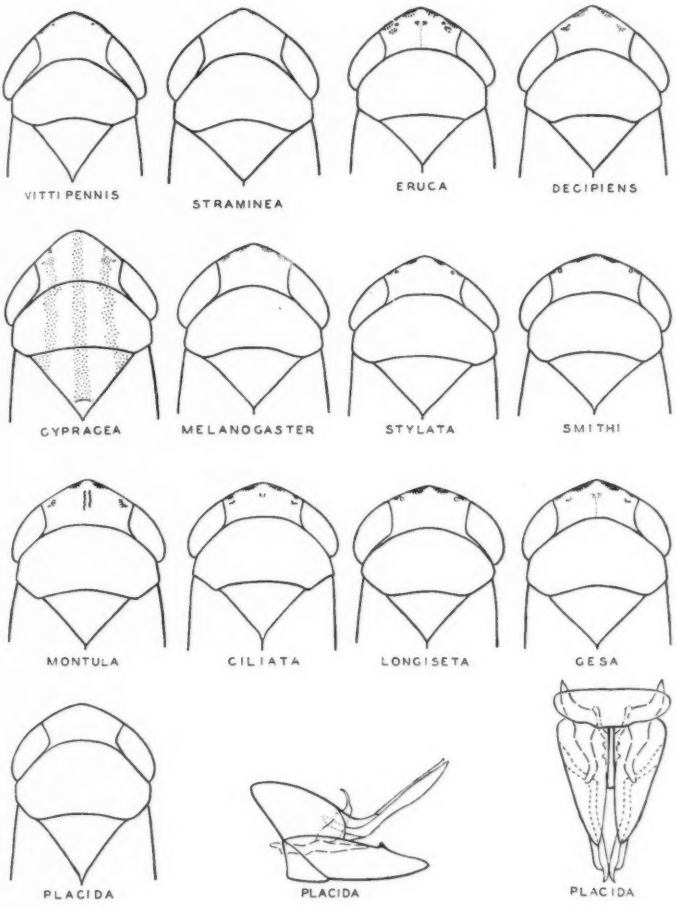


Plate I. Upper—Illustrations of the heads of the species of the Genus *Cyperana*. Lower—Head, lateral and ventral views of the male genitalia of *Paluda placida*.

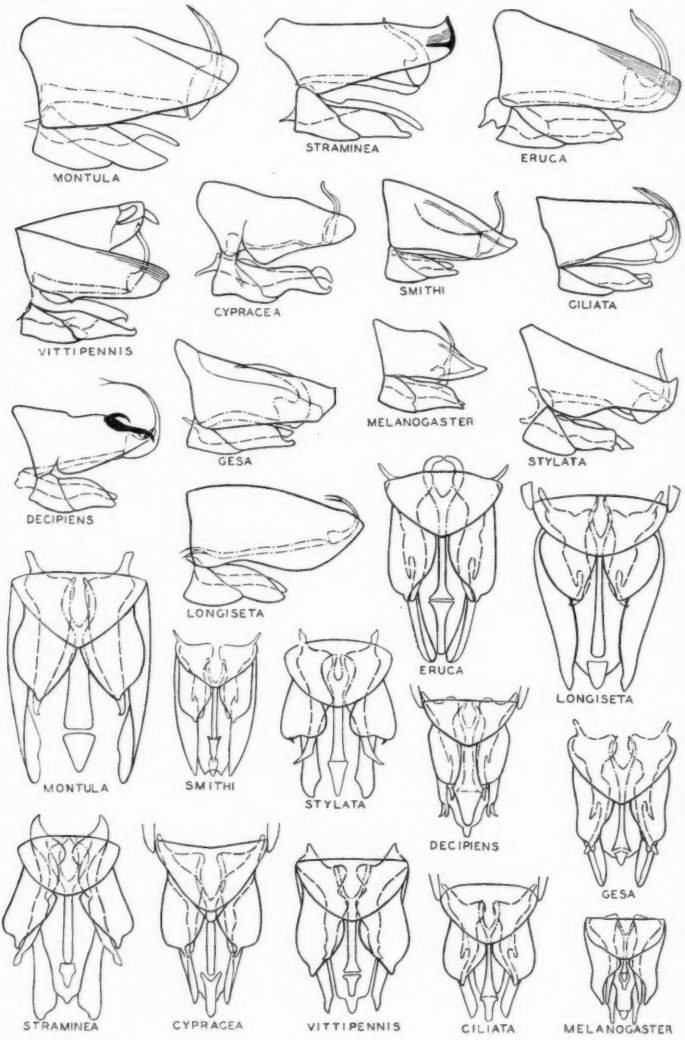


Plate II. Upper—Lateral views of male oedagi in situ.
Lower—Ventral views of male oedagi in situ.

New Moss-Mites, Chiefly Midwestern—II.

Arthur Paul Jacot

This paper is in large part based on material from Mammoth Cave, Kentucky, Turkey Run, Indiana, and Urbana, Illinois, collected and submitted to me by Dr. Orlando Park of Northwestern University. This material is being returned to the Zoölogy Department of Northwestern University. Lot numbers including an F are to be deposited at the U. S. National Museum, others at the Museum of Comparative Zoölogy. Colors given are always as seen by transmitted light (under the microscope).

Nothrus truncatus silvicus subsp. nov.

Figs. 3 and 4

As the species (1, p. 14) but pseudostigmatic organs burred; interlamellar and notogastral bristles short, the latter overreaching barely half the interspaces, clavate, the posterior bristles nodose, strongly clavate (Fig. 3); bristles d2 reaching posterolateral corners of abdomen; bristles e1 porrect, with broad nodose head (Fig. 4); bristles e2 only slightly more remote than d1, only slightly bent, conspicuously projecting (Fig. 3).

Material examined: Six specimens from soil sample, seventy year pitch pine-oak woods, laboratory grounds, Bent Creek Experimental Forest, Buncombe Co., N. Car.; taken January 7th 1935, slide 34F21-7 *(cotypes)*. One specimen from forest floor, Mammoth Cave, Ky.; taken March 28th 1936. Two specimens from Turkey Run, Indiana; taken April 12th 1936.

Nothrus truncatus robustus subsp. nov.

Fig. 2

As the species but interlamellar and notogastral bristles longer, the anterior notogastral almost overlapping (Fig. 2); bristles e1 porrect; bristles e3 more definitely clavate.

Cotypes: Three specimens from sphagnum of cranberry bog, Cliff Island, Casco Bay, Me.; taken September 17th 1925, slide 2544n3.

Nothrus silvestris bistilus subsp. nov.

Fig. 1

As the species (12, p. 458, pl. 7, figs. 4 to 4b) but abdomen more depressed so that in lateral aspect it projects <-like, thus overhanging bristles f1 and f2 which are moreover relatively shorter (Fig. 1); mesal bristles of dorsum more depressed; bristles e3 at least twice length of e2 (and e1), distal end curved markedly downward.

Cotypes: Five specimens from Andropogon stand, Case place, Bent Creek

Experimental Forest, ten miles south of Asheville, N. Car.; taken February 6th 1935, slide 34F24-14.

Nothrus silvestris exilior subsp. nov.

As species but bristles very slender, f2 (and f1) short, not visible in dorsal aspect; e3 at least twice length of e2, distal end bent downward, sometimes even sharply bent forward.

Cotypes: Five specimens from forest floor, Mammoth Cave, Ky.; taken March 28th 1936, slides 106, 109, 111, 116 119 (Zoölogy Dept., Northwestern University).

Nanhermannia dorsalis (2, p. 77)

Fig. 5

This species, first described from Sea Cliff, Long Island, N. Y. by Nathan Banks as a Carabodes, and again described from Lake City, Fla., by Berlese as *Nanhermannia coronata* (6, p. 100, pl. 7, fig. 85) is found throughout the eastern United States. It shows considerable variation in the development of the processes along the dorsoposterior edge of the cephaloprothorax. The single type specimen seen by me, is identical to Berlese's figure (see also my Fig. 5). This form represents the least development of the ridge. In the other form the ridge is developed as two elongated lobes which overlap anterior edge of notogaster. As the two forms may be found in the same handfull of litter, and as this is the only difference between them, I regard the one merely as a form of the other. That with the elongated lobes is identical with specimens from Regensburg in Bavaria, usually regarded as *N. elegantula* (6, p. 100, pl. 7, fig. 84).

Nanhermannia dorsalis elegantula comb. nov.

Fig. 6

Differs from the species only in the form of the dorsoposterior ridge of the cephaloprothorax, which in this form, is developed as a pair of elongated lobes which overlap anterior edge of notogaster (Fig. 6).

Hermanniella subnigra setacea subsp. nov.

Differs from the species (8, p. 131, pl. 5, figs. 30 and 31) in that the rostral bristles are quite slender and smooth, contrasting markedly with the interlamellar; pseudostigmatic organ head fimbriate; anal and genital apertures quite near (distant not over a fourth length of genital).

Holotype: from forest floor, Mammoth Cave, Ky.; taken March 28th 1936, slide 131 (Zoölogy Dept., Northwestern University).

H. punctulata columbiana (5, p. 224, pl. 20, fig. 59) must be identical for it comes from the same material. Professor Cyrus R. Crosby has told me that in 1904 to 1906 while at the University of Missouri he ran a Berlese trap with leaf mould from along Hinkson Creek (which runs through the University campus). Some of the mites thus secured he sent to Pavesi in exchange for phalangids. Soon after, Pavesi died, and Berlese obtained the material. Interim Crosby gave the rest of the material to Ewing when he was

a graduate student at Cornell University. Thus Ewing's and Berlese's Columbia, Missouri species are topotypic even in a restricted sense.

Eremobodes gen. nov.

Lamellae developed as slender ridges, free at distal end; with a broken translamellar ridge; interlamellar bristles anterior; center of vertex elevated, domelike; posterior edge of cephaloprothorax with two blunt interpseudostigmatic spurs; anterolateral corners of notogaster angular to slightly produced; sides of thorax sculptured; tectopedio II well developed; tectopedia III developed as a cupping spur; apodemata well developed; parasterna IV broad, the sternum slender; genital and anal apertures distant at least length of genital; anterior face of coxae III pointed; (ungues monohamate).

Type: *Eremobodes pectinata* sp. nov.

Eremobodes pectinata sp. nov.

Figs. 14 and 15

Diagnostic characters: Pseudostigmatic organs slender, curved sicklelike, pectinate, with seven to eight well spaced pectinations which are slightly longer than their interspaces; interlamellar and notogastral bristles stout, blunt, rather stiff, not long; lamellar bristles fairly long, tapering, curved to lie close to face of cephalon; rostral bristles short, fine, inconspicuous; notogaster smooth.

Description: Size small: length of females 0.287 mm., breadth 0.15 mm.; color amber; rostrum barely distinct only slightly impressed at base; sides of cephaloprothroax sculptured by incomplete network of polygons, best developed between distal half of lamellae and legs I, sides of thorax sculptured with fine granules, especially above legs III; exopseudostigmatic bristles not discernible; a slight ridge mesad of lamellae along proximal half, a transverse ridge between interlamellar bristles which are situated at center of lamellae; pseudostigmata with a well developed posterior callus; free ends of lamellae twice as long as broad; notogaster somewhat irregular or bumpy; of the twenty notogastral bristles a1 are more posteriad than b2, b1 are on same transverse plane as c2; ventral plate broad; a ridge posterior to anal aperture extends anteriad to transverse plane of anterior anal bristles; ad2 and ad3 well developed; ad3 mesad of center of its cover; ad2 more remote than diameter of aperture; ad1 posteriad of anterior edge of aperture, more remote than ad2; paramesal bristles as remote as ad2, halfway between the apertures; anterior end of anal covers only slightly lobed; genital aperture much smaller than anal, with six bristles disposed as in figure 15; apodemata I slender; sternum broad between apodemata I, evanescent between parasterna I. Leg segments rather stout, bulby, angular; tibiae I much shorter than tarsus, with prominent tubular apophysis for the long dorsodistal bristle; other bristles of moderate length not conspicuously specialized.

Material examined: Eight specimens from litter of deciduous woodlands, Bent Creek Experimental Forest, Buncombe Co., N. Car.; taken October 1st 1934, slide 34F6-9 *(cotypes)*. Five specimens from soil sample of same woodland and two specimens from root six inches deep. Four specimens from

litter above the soil sample. Four specimens from soil sample of Rocky Cove, about 500 feet above other locations.

Carabodoides gen. nov.

Superficially resembling Carabodes but with lamellar ridges similar to Eremobelba; genital and anal apertures closer together than length of genital; tectopedia III well developed; shoulders of notogaster with projecting angle which bears bristle a1; in lateral aspect the cephaloprothorax is sharply bent at distal end of lamellae, and the rostrum projects.

Type: *Carabodoides saccharomycetoides* sp. nov.

Carabodoides saccharomycetoides sp. nov.

Fig. 13

Diagnostic characters: Pseudostigmatic organs and notogastral bristles clavate, fimbriate; notogaster sculptured by an irregular network of low ridges which resemble yeast growths (whence the specific name), anterior edge of notogaster sculptured with angular network of rather fine caliber (Fig. 13); lamellar bristles stout, finely short-ciliate.

Description: Size of larger females 0.467 mm., breadth 0.25 mm.; color light chestnut; cephaloprothorax seen from above, conical, flat sided (anterior to tectopedia I), rostrum barely set off; seen from sides angular, the rostrum projecting as a flat baseboard; lamellae developed as slender, rugose, translucent ridges, the distal end of which is closely appressed to cephaloprothorax, lamellae subparallel, fairly close together, sharply bent to reach pseudostigmata; sides of cephalothorax strongly areolated; interlamellar area with a sigmoid ridge and a few meshes of angular areolations; posterior end of sigmoid ridge raised to form a low crest the posterior edge of which is rugose; dorsoposterior part of prothorax roughened by a cluster of nodules; rostral bristles fine, strongly surved; interlamellar bristles fine, short, barely projecting in lateral aspect; sides of notogaster sculptured with an angular network. Venter with rather short bristles, so much smeared with foreign matter as to make their location difficult to discern (Fig. 13 includes only those seen with certainty); anal covers with long anterior lobe; bristles of genital cover not constant in position but 1 and 2 always on anteromesal quarter of cover, 3 always on anterolateral quarter, and 4 (sometimes accompanied by a fifth) always close to posterior and posterolateral edge of cover; ventral plate with a diagonal fold posterolaterad of anal aperture and with various accessory internal ribs (Fig. 13).

Cotypes: Twenty-eight specimens from litter of 30 year white pine plantation, Biltmore estate on Asheville-Brevard road, N. Car.; taken February 25th 1935 352o8, *(cotypes*—to be deposited at the U. S. National Museum).

Carabodes apicalis (1, p. 13) belongs in this genus. It has more slender, less clavate notogastral bristles and different sculpturing.

Epieremulus geometricus (7, p. 332) may be related. Concerning Epieremulus, Berlese says it is like Eremulus but has tectopedia III developed as in Eremaeus. The definition of Eremulus is that it is like Eremaeus but

without tectopedia III. Therefore, as far as the verbal definition goes, Epieremulus would be the same as Eremaeus!

Carabodes omo sp. nov.

Figs. 7 and 8

Diagnostic characters: Abdomen elongate, weakly but distinctly marginate, weakly but distinctly shouldered, areolate; cephaloprothorax elongate; rostral and lamellar bristles stout, spinelike, faintly burred; pseudostigmatic organs, interlamellar, and notogastral bristles clavate, the head fimbriate; apertures rather widely separated.

Description: Average size of females: length 0.43 mm., breadth 0.21 mm.; color chestnut; cephaloprothorax elongate, not abrupt; in lateral aspect: prothorax confluent with cephalon which is covered with small, pocklike areolations, dorsum of prothorax sculptured by irregular, rugose, more or less longitudinal ridges; rostrum somewhat pinched together, rostral bristles inserted on distinct nubbins which stand out at sides of rostrum, rostral bristles longer, more pointed, less thickly burred than lamellar; lamellae distinct, free for their entire length, with longitudinal ridge, areolated, extending nearly to rostral bristles; tectopedia I well developed, distal end curving ventrad; interlamellar bristles fully as long as pseudostigmatic organs, inserted on vertex near anterior limits of prothorax, strongly rib-veined; pseudostigmatic organ head unveined, quite broad, compressed (Fig. 8); notogaster with ten clavate, veined, fimbriate bristles (Fig. 7). Venter areolate-pocked, the labium more pocked, the ventral plate distinctly areolated; all parasterna broad; apodemata well developed; bristles short, except ad2 and ad3, the latter being half length of notogastral bristles, and weakly clavate-fimbriate. Legs not unusual for the genus.

Material examined: Twenty-one specimens from litter of eighty-year old pitch pine-oak woodlands northwest of laboratory buildings, Bent Creek Experimental Forest, Buncombe Co., N. Car.; taken September 13th 1934, slide 34F3.1-7 *(cotypes)*. One specimen from forest floor, Mammoth Cave, Ky.; taken March 28th 1936, slide 138. Five specimens from Urbana, Illinois; taken April 14th 1934, slides 30, 54, 55, 71, and 74.

Related to *C. radiatus* (7, p. 328).

The specific name is a pictograph signifying fimbriate bristles between pocks.

Suctobelbila gen. nov.

Characters much as in Suctobelba but notogaster with but one spur on anterior edge each side of median line.

Type: *Suctobelbila punctillata* sp. nov.

Suctobelbila punctillata sp. nov.

Figs. 11 and 12

Diagnostic characters: Rostrum compressed, slender; cephaloprothorax granular-punctate; a broken, transverse, opaque band at region of translamella; pseudostigmatic organs clavate, sharply bent, head directed anteromesad,

smooth, strongly compressed; notogaster oval, with granular surface, with raised, low discs at insertions of the minute bristles (Fig. 12).

Description: Size (of types): length 0.18 mm., breadth 0.1 mm.; (of others) length 0.16 mm., breadth 0.08 mm.; color pale, greyish yellow; cephaloprothorax short, slender, rostrum descending to a point (Fig. 12); rostral bristles inserted well under rostrum so as not to be visible in dorsal aspect; lamellar and interlamellar bristles not discernible, but a more densely sclerotized oval at usual site of interlamellars; the apparent transverse ridge is the edge view of vertical face formed by the much depressed cephaloprothorax at this point (Fig. 12); posterior edge of cephaloprothorax more densely sclerotized as a lobed band; pseudostigmata broad, directed anterolaterad, not open dorsally, close to edge of notogaster which encroaches heavily on cephaloprothorax so as to actually project between them, entirely covering over acetabulae III; pseudostigmatic organ head smooth, strongly compressed, like a knife blade but warped downward so as usually to show the face of the blade (obliquely). Notogaster rendered angular by the raised areas of the bristle insertions (Figs. 11 posterior edge, and 12); anterior edge thinner, spur well developed, no bristle discernible; posterior edge somewhat mammilate. Ventral plate shallowly pocked, making the very short bristles difficult to distinguish; anal aperture relatively small; cover bristles close to lateral edge; pseudofissura oblique; bristles ad3 more approximate than cover bristles; ad2 laterad of posterior corner of aperture, distant from aperture; ad1 as remote as ad2, on transverse plane far anteriad of anterior edge of aperture; anterior margin of genital aperture not strongly angled, gently curved; each cover with five or six bristles arranged somewhat as in Fig. 11; sternum rather slender throughout its length; apodemata I slender; II-III well developed.

Cotypes: Eighteen specimens from spaces between Andropogon clumps, twelve year old-field, Case place, Bent Creek Experimental Forest, Buncombe Co., N. Car.; taken February 6th 1935, slide 34F24-12.

Oribella crosbyi clavata subsp. nov.

Fig. 25

As species (4, p. 9; 5, pl. 21, fig. 84) but pseudostigmatic organs clavate (Fig. 25) instead of "very long fusiform, very acute" (Fig. 24).

Holotype: From forest floor, Mammoth Cave, Ky.; taken March 28th 1936, slide 79 (Zoölogy Dept., Northwestern University).

Gymnodampia gen. nov.

In dorsal aspect resembling Gymnodamaeus and Damaeus, in ventral aspect resembling Oppia (when the generic name). Cephaloprothorax broad, strongly constricted between lamellar and interlamellar bristles, and between cephaloprothorax and abdomen; sculpturing restricted to two sclerotized rings (tubercles) surrounding the interlamellar insertions, and a boss at base of lamellar bristles; rostrum variously incised; pseudostigmata projecting prominently at sides; tectopedia II highly developed; tectopedia III developed as in Oppia; notogaster high, each shoulder developed as a projecting ridge or flange; aperture of ventral plate widely separated; legs as in Oppia.

Type: *Amerobelba setata* (7, p. 332).

Although Berlese regarded this species as an Amerobelba, I consider it as more closely related to Eremobelba, which it, at least superficially, resembles. It is astounding that neither Banks nor Ewing described this large species which I have from Connecticut and western North Carolina. There seems to be no subspecific differentiation.

Porobelba parki sp. nov.

Fig. 16

Diagnostic characters: Pseudostigmatic organs stout, slenderly clavate; tectopedia II small; notogastral bristles sharply bent near insertions so that they lie parallel to surface of notogaster, quite straight (Fig. 16), anterior four directed forward; anal and genital not touching but rather close to each other; dorsal face of all femora with a stout, strongly curved, coarsely barbed bristle.

Description: Size small, total length of body 0.34 mm.; color pale; cephalothorax relatively high, rostrum flat, barely distinct; rostral and lamellar bristles simple; interlamellar bristles directed backward, short, sigmoid, inserted close to pseudostigmata; exopseudostigmatic bristles well-developed, not prominent; pseudostigmatic organs quite long, with small head which is abruptly pointed; tectopedia III developed as a stout ridge, much longer than tectopedia II, notogastral spurs quite slender, the twenty-two notogastral bristles normally arranged; the anterior ones quite flat, the posterior ones more curved; bristles ad1 to ad3 quite conspicuous, ad2 and ad3 laterad of aperture; barbs of dorsal bristles of femora arranged in two or three rows; dorsal bristle of femora IV with about fourteen barbs.

Material examined: Four specimens from Urbana, Ill.; taken April 14th 1934, slides 41 (holotype), 35, 47, and 58 (paratypes). One specimen from forest floor, Mammoth Cave, Ky.; taken March 28th 1936, slide 136. One specimen from Turkey Run, Ind.; taken April 12th 1936, slide 171.

Liacarus nitidus fissuratus subsp. nov.

Figs. 9 and 10

As species (1, p. 10) but the two lamellae so close together as to leave a narrow fissure between them (Fig. 9); moreover, whereas in the species the mesal tooth of the lamellae tends to be lost, in this form it is the lateral cusp which tends to disappear (Fig. 10).

Holotype: from Carlé Woods, Des Plaines, Illinois; taken April 6th 1935, slide 20 (Zoölogy Dept., Northwestern University). The holotype of the monodentate form of figure 10 is on slide 19 (same lot).

Xylobates capucinus (4, p. 2)

As described by Berlese this species is barely recognizable, but as the genus has very few species, as he regarded the Italian and American (Columbia, Missouri) specimens as identical, and as my American and Regensburg specimens are identical and include the size of *X. capucinus*, I regard *Xylo-*

bates capucinus as a holarctic species represented by local races or subspecies in different parts of its range.

As *Oribata oblonga* (9, p. 73, pl. 11, fig. 37) is the same size, and is from the same locality, niche, and collector as was Berlese's material (see note under *Hermanniella punctulata columbiana,* above), it is a synonym.

The species figured by Willmann (12, p. 160, figs. 238 and 239) as *Protoribates lophothrichus* is entirely different from Berlese's species (3, p. 27, pl. 2, fig. 48) for the short pteromorphae are different as well as the non-clavate pseudostigmatic organs. Moreover, the genotype has a narrow rostrum and four short bristles extending beyond posterior edge of abdomen.

The outstanding characteristics of *Xylobates capucinus* are the broad rostrum, the short, fine lamellar bristles which never project beyond the rostrum, the relatively short, *stout* interlamellar bristles, and the relatively short postanal bristles (ad2 and ad3) which rarely extend beyond edge of notogaster, though ad3 do in some cases.

Xylobates capucinus robustior subsp. nov.

Figs. 22 and 23

As the species but size slightly larger than the type: length 0.47 to 0.53 mm., breadth 0.3 to 0.34 mm.; interlamellar bristles normal, sparcely, faintly ciliate; pseudostigmatic organ head, slender, its diameter about the length of the cilia, seven or more cilia along edge of head (Figs. 22 and 23) extra cilia often appear on opposite edge of head; mesonotal bristle mesad of its porose area; anterior pair of sternal bristles more approximate than middle pair; paramesal bristles nearer genital than anal aperture, ad3 conspicuous beyond abdomen.

Cotypes: Thirty-seven specimens from surface of soil (beneath the litter) of a seventy year old, mixed woodland, laboratory grounds, Bent Creek Experimental Forest, Buncombe Co., N. Car.; taken January 7th 1935, slide 34F21-1.

Xylobates capucinus angustior subsp. nov.

As the species but much more slender and much smaller: length 0.328 to 0.44 mm., breadth 0.16 to 0.246 mm.; more colorless; head of pseudostigmatic organ with only four to six cilia; ad3 barely visible beyond abdomen; dorsal face spine of tibiae I reaching hook of unguis (when latter is drawn back).

Cotypes: Sixteen specimens from Andropogon sod of forty year pasture between wooded slopes, on Asheville-Brevard road, twelve miles from Asheville, N. Car.; taken October 13th 1934, slide 34F13a.

Xylobates longisetae sp. nov.

Figs. 17 to 21

Diagnostic characters: Rostrum fairly broad; lemallar bristles long, extending well beyond rostrum; interlamellar bristles long (Fig. 17).

Description: Size fairly large: length (of specimens from Mammoth Cave,

Ky.) 0.52 to 0.55 mm., breadth 0.32 to 0.34 mm.; color pale, buff; body stout, rounded; cephaloprothorax short; rostrum distinct, blunt (Fig. 17); rostral bristles simple; lamellar bristles faintly pauciciliate; interlamellar bristles long, apparently flattened, often with a spiral twist, pointed; lamellae with distal end distinct from cephaloprothorax in dorsal aspect; pseudostigmatic organs with relatively broad head, the cilia shorter than breadth of head (Figs. 18 and 19), interspaces shorter than length of cilia, about eight cilia along edge of head (including distal point); notogaster with small porose areas, adalar bristle distant from its porose area (Fig. 17); mesonotal porose areas much more approximate than adalar bristles; ventral plate with broad wings; anterior sternal bristles as remote as middle pair; third pair minute, very approximate, and close to genital aperture frame or against it; sternum very slender; mesal end of apodemata IV close to apodemata II-III; mesal bristle of parasterna IV posterior to distal end of apodemata IV; paramesal bristles midway between the two apertures; bristles of anal covers longer, the anterior pair more remote than posterior pair; ad1 close to aperture, more approximate than greatest diameter of aperture; ad2 more remote; ad3 much longer, nearer lateral corner of aperture than to median plane; anal pseudofissurae short, on transverse plane of anterior anal bristles or slightly anteriad thereof (Fig. 17).

Tarsi I (Fig. 20) with dorsal spine long, curved, nearly reaching hook of unguis; proximal bristle of ventral face with several cilia, bristle 2 with five cilia bristle 3 rigid, stout, spinelike, with four pectinations; tibiae as in figure 20; genual with long dorsodistal bristle; femora without distinct flange. Tarsi II (Fig. 21) with dorsoproximal bristle ciliate, bristles 2 and 3 stout, curved, blunt (spinelike); ventroproximal bristle multiciliate, bristle 2 similar to ventral face bristle 3 of tarsi I but with one more pectination; femora with wide flange which is drawn out distally in a lobe (Fig. 21).

Cotypes: Seventeen specimens from forest floor, Mammoth Cave, Ky.; taken March 28th 1936, slides 97, 90, 157, 165, 160 and 159. The Northwestern University collection also includes a specimen from Turkey Run, Indiana.

Ceratozetes gracilis subaquila comb. nov.

Last year (10, pp. 549 and 550) I described some forms of *C. subaquila.* I now have to record that they are subspecies of *C. gracilis* of Europe. Although I have not seen specimens from the type locality (Epping Forest, Devon, England) or from any part of England, I find that the form of Regensburg is quite similar to *C. subaquila,* differing chiefly in the following respects: paramesal bristles much closer to genital than to anal aperture (in *C. subaquila* they are midway), anterior portion of genital aperture frame wide enough to include the third pair of sternal bristles (in *subaquila* these bristles are anteriad of frame), sternum more strongly developed (weak to lacking in the American form, anterior half entirely lacking). There are also differences in the disposition of the bristles of the *posterior* half of the notogaster. The pseudostigmatic organs are always the same: flat, straplike, ciliate on both edges.

Thus the form of *C. subaquila* becomes **C. gracilis subaquila curtispina**

comb. nov., while the other subspecies becomes **C. gracilis longispina** comb. nov. and its form **C. gracilis longispina minor** comb. nov. The pseudostigmatic organ remains constant through all these forms.

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U. S. Forest Service,
New Haven, Conn.

PLATE 1

FIGURES

Nothrus silvestris bistilus subsp. nov.

1. Lateral aspect of abdomen to show form and position of bristles; ratio x75.

Nothrus truncatus robustus subsp. nov.

2. Lateral aspect of abdomen to show form and position of bristles; ratio x75.

Nothrus truncatus silvicus subsp. nov.

3. Dorsal aspect of half of the posterior end of abdomen; ratio x100.
4. Bristle e1; ratio x440.

Nanhermannia dorsalis (2, p. 77)

5. Dorsal aspect of half of prothorax to show posterior edge of same; ratio x200.

Nanhermannia dorsalis elegantula comb nov.

6. Dorsal aspect of half of prothorax to show posterior edge of same; ratio x200.

Carabodes omo sp. nov.

7. Bristles of posterior edge of notogaster; ratio x440.
8. A pseudostigmatic organ; ratio x440.

Liacarus nitidus fissuratus subsp. nov.

9. Dorsal aspect of cephaloprothorax; ratio x200.
10. Dorsal aspect of lamellae of an individual with lateral cusps of lamellae abortive; ratio x200.

Suctobelbila punctillata gen. et sp. nov.

11. Dorso/ventral aspects, legs and mouth parts omitted; ratio x440.
12. Lateral aspect, legs and mouth parts omitted; ratio x200.

PLATE 2

Carabodoides saccharomycetoides gen. et sp. nov.

13. Dorso/ventral aspects, legs and mouth parts omitted; ratio x200.

Eremobodes pectinatus gen. et sp. nov.

14. Lateral aspect, legs II to IV and mouth parts omitted; ratio x264.
15. Dorso/ventral aspects, legs and mouth parts omitted; ratio x264.

PLATE 3

Porobelba parki sp. nov.

16. Lateral aspect, legs II and III and mouth parts omitted; ratio x200.

Xylobates longisetae sp. nov.

17. Dorso/ventral aspects, legs and mouth parts omitted; ratio x150.
18. A pseudostigmatic organ, dorsal aspect; ratio x440.
19. A pseudostigmatic organ, lateral aspect; ratio x440.
20. Tarsus I to genual I, lateral aspect; ratio x264.
21. Legs II, lateral aspect; ratio x264.

Xylobates capucinus robustior subsp. nov.

22. A pseudostigmatic organ, lateral aspect; ratio x440.
23. A pseudostigmatic organ, dorsal aspect; ratio x440.

Oribella crosbyi (4, p. 9)

24. A pseudostigmatic organ, lateral aspect; ratio x440.

Oribella crosbyi clavata subsp. nov.

25. A pseudostigamtic organ, lateral aspect; ratio x440.

PLATE 1

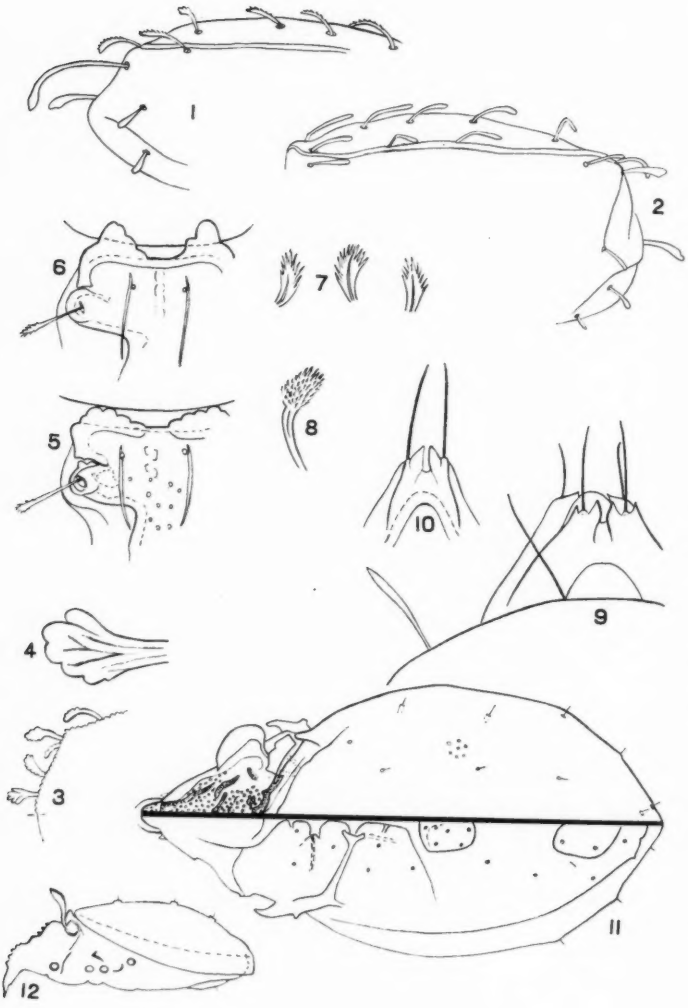


PLATE 2

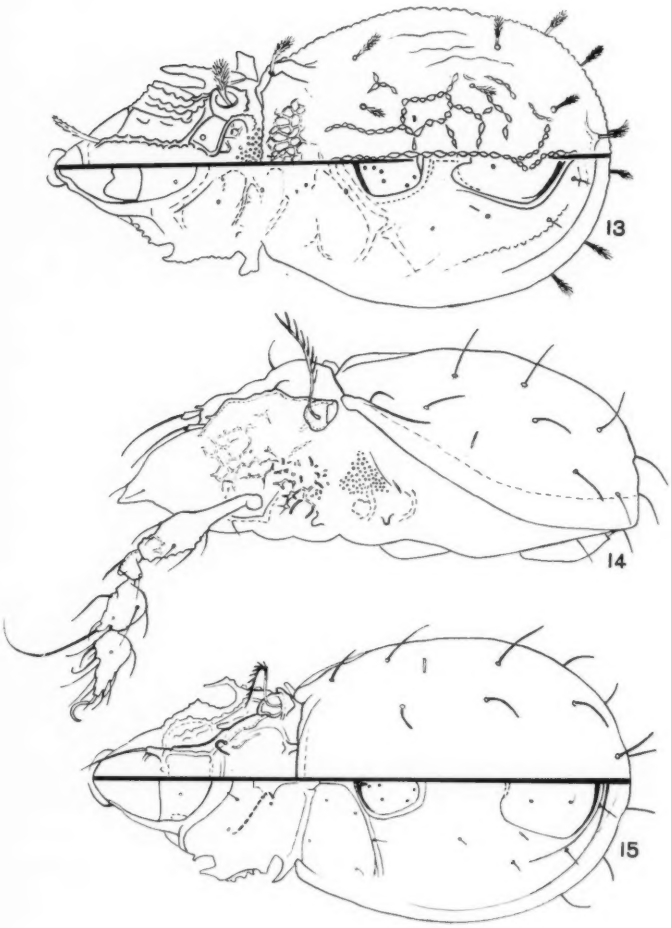
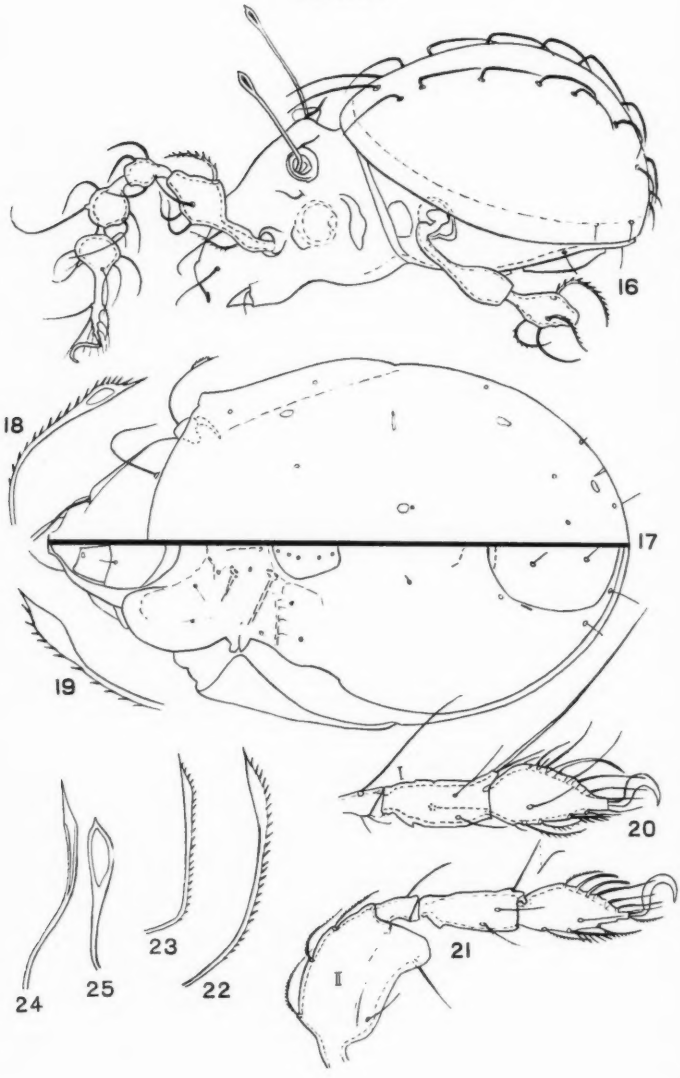


PLATE 3



The Biology of Physa anatina Lea, a Snail Living in a Sewage Treatment Plant[1]

Thelma Fish Brown

Relatively little specific information is available regarding the biology of any species of Physa, consequently, when Physa made its appearance in extreme abundance in the sewage treatment plant of Urbana-Champaign, Illinois, there seemed to be exceptional opportunity for studying certain aspects of the life cycle. The following statements give a general idea of the plan of the treatment works. Raw sewage enters the Imhoff tanks in which considerable bacterial action takes place. From here it is pumped into the sprinkling filters where jets of the sewage are forced into the air for aeration. As the aerated sewage soaks through the deep beds of crushed stone, organic matter is removed. The sewage is then sent through conduits to the secondary settling tank, from which a part of the final effluent is diverted into an experimental lagoon, the remainder being released into the Saline Drainage Ditch, a tributary of the Big Vermilion River. In the present investigation, collections from different regions of the plant have been studied in an effort to determine possible restrictions or limitations of breeding areas within the system. These field studies have been supplemented by laboratory observations on the snails to determine, in so far as possible, the rate of reproduction and rate of growth.

The investigation was begun in February, 1932. Observations were made continuously until August of the same year, were resumed from June to August, 1933, and from September to April, 1934-1935. Attempts to secure field information during the spring of 1933 were fruitless because of an extended period of heavy rains which brought floods interfering with the normal operation of parts of the plant serving as the habitat of Physa.

This study was suggested by Professor H. J. Van Cleave, and has been carried on under his supervision at the University of Illinois. All of the snails in collections from the plant are *Physa anatina* Lea with the exception of eight individuals of *Fossaria modicella*. The Fossarias were in collections from the secondary tank and Saline Ditch stations, and probably had migrated into the plant from the stream where Fossaria occurs regularly.

The writer is indebted to Mr. Frank C. Baker, Curator of the Natural History Museum of the University of Illinois, for many conferences, and to Dr. H. S. Pepoon of the Illinois State Natural History Survey for the identification of the moss, Fontinalis, on which snails were fed in the laboratory. Mr. G. H. Radebaugh, District Manager of the Sanitary District, has given much valued information and assistance. The writer is especially indebted to

[1] Contributions from the Zoological Laboratory of the University of Illinois, No. 498.

Dr. William J. Clench of the Museum of Comparative Zoology for the identification and for the information that this is the first record of the species as far north as Urbana, Illinois. The discovery of a well established colony of *Physa anatina* in east-central Illinois materially extends the recorded range of this species. The introduction of the snails into the sewage treatment plant was probably accidental, through human agencies. However, the fact that this species has become established in the stream receiving the effluent of the treatment works gives evidence that the physical and climatic conditions in the streams on this margin of the recorded range are not hostile to its further spread. Though Miss Dawson (1911) reported *Physa anatina* in Michigan, the specimens so identified were later found to be *Physa michiganensis*. Dr. Clench states in a letter that the center of the range of *Physa anatina* is in Kansas and Oklahoma.

The Saline Ditch, which receives the effluent from the plant, was dredged in 1908, and since then has been known as the Saline Drainage Ditch. At the point where the effluent from the plant dashes over large rocks for a final aeration before flowing along with the stream, the bottom fairly seethes with *Physa anatina* during the summer months. Snails of all sizes varying from 1.6 mm. to 9.0 mm. were collected at this station. It becomes apparent that this species is adaptable in its food habits, when one considers that the Saline Ditch does not supply organic material such as is to be found in untreated sewage. Even more impressive is the fact that the most successfully kept laboratory specimens were placed in tap water with only a sprig of the moss, Fontinalis, for food.

The method of the introduction of snails into the plant is unknown. The effluent from the sprinkling filters was turned into the secondary tank for the first time on August 28, 1929. The following quotation from the Fourth Annual Report of the Urbana-Champaign Sanitary District (p. 15) shows that numerous snails were sighted within a month's time after operation began. "During the last few days of September (1929), bushels of live snails were discovered coming into the secondary settling tank. Upon investigation it was found that these were coming from the sprinkling filters. This phenomenal situation proves beyond doubt the presence of a high amount of dissolved oxygen in the lower part of the filters." As is mentioned later, *Physa anatina* breathes atmospheric air directly into the lung, therefore the amount of dissolved oxygen would be relatively unimportant as a factor determining favorable or adverse conditions for the existence of this species. In fact, pulmonate snails have little or no value as indicators for measuring the relative suitability of water for supporting aquatic life.

Engineers Pearse, Greeley, and Hanson reported that snails occurred at the Fort Worth, Texas, plant. Later Professor Van Cleave was able to secure a sample of these snails, which Dr. Clench has identified as *Physa halei* Lea. So far as the writer is aware, the snails of that plant have not been studied biologically. Thus two species of Physa are known to adapt themselves to conditions found in sewage plants.

There is no direct observation indicating that the breeding of Physa is restricted to any single region of the treatment plant. Evidences gained in the present study indicate that mature individuals of breeding size occur in all favorable locations from the beds of the sprinkling filters on into the Saline Ditch, which receives the effluent. The snail may breed in the lower, large rock layer of the sprinkling filter, for, although the evidence is not conclusive, there does seem to be a progressive increase in range of shell size in population samples, proceeding from the sprinkling filter toward the stream. In that case, there must be adults living among the rocks of the sprinkling filter or no eggs would be deposited there. Collections of snails taken from tubes leading into the lower levels of the filter bed were made up of both mature and young snails in assorted sizes, giving direct support to the belief that the entire life cycle may be completed in the filter beds. There is a bare possibility of migration from the sluice ways back to the filters, but it seems improbable, since the water current would offer a considerable obstacle to the snails from the other parts of the plant, reentering the outlets from the filter beds. At the times of collecting, there never have been snails at the outlets in abundance great enough to give evidence of active migration against the normal flow of the treated sewage.

At least once a year and usually twice (July and November) twenty-five to thirty bushels of the snails and empty shells are removed from the conduit of the secondary settling tank, where the chief collecting for this study was done. Dead shells from all parts of the plant tend to be carried to the secondary tank. During most of the year, an abundance of living specimens can be taken from the walls of the conduit with a collecting dipper, and a layer of dead shells several inches deep is to be found in the bottom of the conduit. The number decreases very perceptibly during the winter months, and, judging from the samples taken, the majority die, leaving only a relatively few individuals. These, however, range in size from large adults to small young (8.9 to 2.3 mm.). Collections were also made at the sprinkling filter outlets, the secondary settling tank proper, Saline Ditch, and the lagoon, which receives part of the purified end products of the treatment works and supports fish life as a demonstration of the condition of the water released to the stream.

In addition to seasonal changes, operating practices have caused radical differences in results from some of the collecting stations. Periods of high water seriously hampered collecting from the stream, and at times interfered with normal operation of the plant. Drainage and chemical treatment of water in the lagoon likewise prevented collection of snails on a few occasions. Consequently, it was impossible to secure representative samples from all stations for each date of field collecting.

Analysis of Samples

The specimens brought to the laboratory to be preserved for statistical study were dropped into boiling water for one minute and then preserved in alcohol. The preserved samples taken on different dates from various stations

within the plant were later measured. The results are shown in Tables 1 and 2. As has been stated before, the evidence presented by these data is not

TABLE 1

Comparison of collections of Physa taken from five stations at the sewage disposal plant during summer months. Table is based upon a study of 150 individuals from each station.

	Average Size in mm.				Range in mm.		
	7/32	6/33	7/33	Total Av'ge	7/32	6/33	7/33
Outlets from Sp. Filter	3.510	4.2	3.852	3.854	1.7–7.1	2.3–6.0	2.0–5.9
Conduit of Sec. Tank	3.966	4.526	4.278	4.257	2.2–7.8	2.5–6.5	2.8–9.0
Secondary Tank	4.512	5.184	4.947	4.881	1.9–7.3	2.1–9.3	2.2–7.8
Salt Fork	5.006	4.98	4.338	4.775	2.7–7.9	3.1–8.5	1.6–8.9
Lagoon	----	5.518	5.276	5.397	----	2.7–9.4	2.6–7.0

TABLE 2

Comparison of collections of Physa taken from five stations at the sewage disposal plant during winter months. Table is based upon a study of 200 individuals from each station.

	Average Size in mm.					Range in mm.			
	9/34	10/34	11/34	12/34	Total Av'ge.	9/34	10/34	11/34	12/34
Outlets	4.196	4.637	4.459		4.43	2.1–6.3	1.9–7.4	2.8–6.0	
Conduit	4.698	4.86	5.769	5.12	5.1	2.4–7.9	1.7–7.6	2.3–9.3	2.1–11.1
Second. tank	4.903	5.029	5.133	4.52	4.89	1.7–7.6	2.7–8.7	1.6–8.6	3.0–6.9
Salt Fork	4.792	4.992	5.491	----	5.09	2.8–6.1	.7–7.1	3.6–9.0	-----
Lagoon	5.041	----	----	----	5.041	3.5–6.9	----	----	-----

conclusive, but there does seem to be a progressive increase of size range proceeding from the sprinkling filter to the Saline Drainage Ditch. This might indicate that most of the breeding takes place in the sprinkling filter, and that the snails migrate through the conduit of the secondary tank, on through the secondary tank proper, until the full grown adults reach the lagoon or Saline Ditch. However, the fact that young as well as adults are found in all the collecting stations proves that the breeding locations are not strictly limited.

Rearing Physa anatina

In addition to the field and laboratory study of distribution of *Physa anatina* within the sewage treatment plant, the problem of the biology of the species was attacked from an experimental point of view. Experiments were devised and carried out to secure data on the length of life, rate of individual growth, and information on the reproductive habits of this species. Keeping the adult snails, as well as the recently hatched young alive in the laboratory has been the greatest difficulty encountered in this study. During the course of the investigation two different methods of keeping individuals under continuous observation were attempted. In the belief that ample space was a requisite for maintaining favorable growing conditions, quart jars were used at first as containers, but subsequent experience showed that smaller containers gave better results. The snails were first isolated as individuals or pairs and kept at room temperature in quart jars with a sprig of Elodea and some filamentous algae. A record of the number of eggs, the date of deposition, and date of hatching was placed on the sides of the jars beside each egg mass. A notebook record was also kept for each collection. In preparing the material for the second series of experiments in 1932, which proved more successful than that kept in the quart jars, three ounce, wide-necked bottles were used. Each bottle was filled about two-thirds full of water and one snail or a pair of snails and lettuce were placed in each. Tap water or water from the disposal plant seemed to work equally well. Aerated, distilled water was also tried. Krull (1931) states that air should not be bubbled into the water containing snails. This observation was confirmed when snails soon died in the jars into which air was bubbled. To maintain fairly uniform conditions, the bottles were placed in the basement, set on a platform in a tank of water with average temperature of 22° C. The water level came about half way up the sides of the bottles. The room was only semi-lighted except when data were being taken, thus furnishing a condition similar to the original habitat.

The large amount of waste material given off and the remains of the lettuce accumulated rapidly, and during the first study were removed every other day. This was accomplished by running the mouth of a small pipette over the bottom of the bottles. The snails clung tightly to the glass and resisted a moderate amount of suction. The water was then replaced and fresh lettuce added. In later studies, the excrement was removed only rarely, and results were equally good or better. In order to keep the snails from crawling out of the bottles into the surrounding water, a cheese cloth cap was placed over the mouth of each bottle and held in place by a rubber band. During the winter of 1934 and 1935, caps made of cotton eliminated the necessity for rubber bands, and thus proved more convenient.

In the third series of study (summer of 1933), the three ounce wide necked bottles were again used, as were the cheese cloth caps. In this series, only one individual of *Physa anatina* was placed in each container. Crabb (1927a) wrote "My experience indicates that in all ponds snails studied, except *Planorbis trivolvis*, "Virgins," i.e. individuals isolated *in ovo*, lay as many

eggs as individuals in mass cultures, and that the percentage of viability of these virgin eggs is as high as that of those from snails reared in mass cultures."

One can appreciate the difficulty of keeping the adult snails alive when it is noted that their average length of life is eleven days. Occasionally an individual lived as long as two months. During the entire study, only three young lived as long as three months, and only two lived beyond four months. Deposition of eggs usually takes place within 48 hours after the snails are collected, but there are many exceptions. No periodicity in laying was noted. The average number of masses per individual during this study was 1.52, and the masses deposited had an average of 8.34 eggs, with a range from two to seventy eggs per mass. The eggs required from four to seventeen days for hatching, and while for the collections checked, 56 percent of them were fertile, only 33 percent of the developed young were successful in emerging from the egg envelope. Masses of eggs were deposited by individuals ranging from 5.3 mm. to 9.6 mm. in size.

Krull (1931) working with *Gyraulus parvus* stated that sooner or later algae or fungi destroy all the snails in laboratory experiments. In the present study, there was no indication of algae being used for food, and there is the possibility that it did increase the death rate. In later experiments, lettuce and a moss (Fontinalis) were substituted for the algae and both were used as food by the snails. The snails' habit of climbing out of the water and drying up has caused considerable trouble. Krull states that food supply is a more general cause for this behavior than is adverse conditions of the water. He adds that young snails will not feed on fresh lettuce, but thrive on decayed lettuce. The writer found decayed lettuce used by *Physa anatina* and both young and old feed upon fresh lettuce. Some of the snails feed greedily, completely skeletonizing lettuce, and producing a large amount of excrement, while others of the same size feed very sparingly. The difference in amount of excrement produced by different individuals of approximately the same size shows that there is a marked individual variation in the rate of metabolism in this species. No experiments were performed to establish a critical basis for understanding the individual metabolic rate, but a number of possible explanations have been considered. Of these, the most plausible seems to be a possible correlation between sexual activity and rate of food consumption. Another possible explanation is that some individuals may have reached a state of senility.

Based upon a study of 80 individuals, Fig. 2 shows the average number of masses deposited by snails of each mm. size between 5 and 10 mm. Figure 1 shows for each month (except April and August) the percentage of individuals which deposited eggs. The study shows that March 1932 was the most prolific month. This period of maximum reproductive activity is followed by a great reduction of reproductive activity in the summer months. With September an increased rate of egg laying is inaugurated, and this persists through the fall months, reaching a maximum in November, when more than 80 percent of the snails produce eggs. Thus there is evidence of a spring

and a fall period of increased egg production, when from 75 to 80 percent of the snails are producing eggs. The above observations are not the results of exhaustive studies, and are offered only as the results of limited experimentation indicative of seasonal trends.

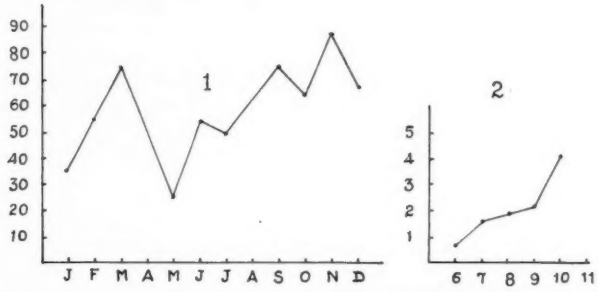


Fig. 1. Graph showing the percent of Individuals which deposited eggs each month. Abscissa represents the months and ordinate represents the per cent of individuals which deposited eggs. Observation for April and August not available.

Fig. 2. Graph showing the average number of egg masses deposited per individual between the sizes of 6 mm. and 10 mm. Based upon records of 80 snails representing collections from all months. Abscissa represents shell height, and ordinate represents average number of masses per individual.

Earlier experiments had given evidence that self fertilization is possible in *Physa anatina*, and the presence of a single individual in each container greatly simplified the recording of data on egg laying. In the third series of experiments, a small piece of an aquatic moss of the genus Fontinalis collected from near the outlets of the sprinkling filter was added to each jar for food. The snails seem to eat it rapidly. In several respects the living moss plants were better adapted to experimental feeding of snails than was the lettuce used in earlier series of cultures. The bottles were placed on a drain board in a stream of tap water at a temperature range from 19° to 22° C. The bottles were examined each morning, and in case an egg mass had been deposited during the night, the adult was removed to another jar. The jar containing the egg mass was then labeled as to date of deposition, number of eggs, and percentage of fertility. Later, observations were added concerning date of hatching, number hatched, size of young, and age attained by young. From the assembled observation it was found that the adults lived longer than those observed in the earlier collections, thus showing that the small bottles are adequate for an individual, and that the semi-light of the basement room is unnecessary. For this study, the size average of the young included both dead and live snails. Some of the young apparently died soon after hatching and this lowered the general average for the group when the check was made at the end of the summer. In the winter study of 1934 and 1935, a sample measurement of the living young was made each week for the first few weeks. This furnished accurate information concerning the rate of growth.

Eggs

The egg masses were indiscriminately deposited on the walls or bottoms of the jars, on the lettuce, on the moss, or on the shells of other snails. As far as was observed, all the eggs were deposited during the night. It commonly has been true, however, that fewer egg masses were deposited during the first night than the second. The egg masses observed were reniform in shape, and contained from two to seventy eggs. This number is distinctly below that characteristic of some other species of the same genus. Baker (1928: 412) states that each egg mass of *Physa gyrina hildrethiana* contains from 130 to 200 eggs. In Baker's observation, the young measured 0.5 mm. in length upon hatching, but they were not observed emerging until 40 days after deposition. There apparently is a wide variation in hatching time for various species of Physa. The eggs are tiny white spots, 0.1 mm. in diameter, and their envelopes are 0.7 mm. in size. The percentage of fertility was approximately 89 for the March collection, and 59 for the May collection. Complete records on fertility were not available. One sterile mass was discovered to contain eggs with crinkly, irregular outlines.

On the first day after deposition, embryos can be seen rotating within the capsules. The young begin to emerge from the capsules between the fourth and seventeenth days, and are 0.6 mm. in length. Though great numbers of the eggs undergo complete development, many of the young fail to escape from the egg case. The cause of this is yet to be determined.

Young Snails

The newly hatched snails crawl up the sides of the jars when they emerge. Those kept in the laboratory at room temperature during the spring and summer died within two weeks. The color condition under which others were kept seemed to be a vital factor during the summer studies. However, for the winter series, laboratory temperatures seemed fairly satisfactory. It was from this group that the two young which reached an age of five months were obtained. Sample measurements made each week for the first weeks of the snails' lives show an average increase in shell size of 0.276 mm. per week.

Physa anatina in the Biology of Sewage Reduction

The importance of *Physa anatina* can be determined only by further experimentation, but it is impossible that an organism present in such numbers and requiring such vast amounts of organic food as bushels of actively living snails would consume, would not play a significant part in the transformation of the organic matter of the sewage in which they live. At the time crude sewage enters the plant it contains 2,100,000 bacteria per cubic centimeter, but when finally treated, the number has been reduced to 700 per cubic centimeter. In this reduction, it is believed Physa has an important part.

As has been previously mentioned, many of the observations contained in this work are not based upon extensive experimentation, and consequently are not offered as conclusive results. However, it is hoped that they will furnish a basis for future comparison.

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A Season with Holbrook's Chorus Frog (Pseudacris ornata)

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The genus *Pseudacris*, comprising about a dozen forms, ranges widely over North America, from Great Bear Lake in the north to Arizona and Florida in the south. It avoids the entire Pacific Coast and the Atlantic Coast from Long Island northward. The Southeastern United States may be fairly regarded as the center of its abundance. Georgia, for example, with no less than five different forms, boasts fully as many as—possibly more than—any other state. The extremely puzzling taxonomy of the genus is still far from being fully elucidated.

Among its congeners, *Pseudacris ornata* is noteworthy for its size and elegance, the paucity of its distributional records, and the meagerness of information concerning its life history. The reason for its having been so largely overlooked is perhaps twofold: comparatively few herpetologists are afield during its winter breeding season, and it apparently leads a very secretive life at other seasons of the year. In my first nine trips to the Okefinokee Swamp region (1912 to 1933, chiefly during the warmer months), I had encountered no more than a single individual of this species (Copeia, 1931, no. 4, p. 159). During the winter of 1935-36, however, I found it to be a fairly common, well-distributed, and vociferous frog in Charlton County, on the eastern border of the swamp. In March I was also fortunate in hearing it in Ware and Liberty Counties, and, in April, in collecting transformed or transforming individuals in Camden and Burke Counties, Ga.

The species was originally described by Dr. Holbrook in 1836, from the vicinity of Charleston, S. C. In subsequent years additional records have accumulated rather slowly, from the Carolinas, Georgia, Florida, and Mississippi. Meanwhile there have not been wanting reports from Texas and Oklahoma, but these have evidently been due to misidentification. The following references are practically all that I have found in the literature, pertaining to the species as understood at present.

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1906 (part: Green Cove Springs, Fla.); Brimley, Proc. Biol. Soc. Washington, vol. 23, p. 11, 1910 (Hastings and Green Cove Springs, Fla.); Nieden, Das Tierreich, Lief. 46, p. 351, 1923 (part: Florida).

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In settling for the winter of 1935-36 in Charlton County, at a point 4 miles west of Folkston, between Spanish Creek and Okefinokee Swamp, one of the objectives I had in mind was further acquaintance with Holbrook's Chorus Frog. It was in this same area that I had found a single example in June, 1929.

On the cloudy and rainy day of December 29, 1935, the thermometer rose to about 68° F.—the first time in ten days that it had been above 60°. At 6:30 p. m. (temp. about 61°) and again at 10:18 p. m. (49°) I heard an unfamiliar frog note from a cypress pond 500 yards to the west. It was much like the voice of the Spring Peeper *(Hyla crucifer)*, but lacked its musical quality and was uttered more rapidly: *kik-kik-kik*, etc. Since it did not correspond to the voice of any one of the other twenty frogs and toads of the region, I suspected at once that here was *Pseudacris ornata*, at the commencement of its vocal season. Within a few days this suspicion became a certainty.

At Waycross, Ware County, the average temperature is 52.3° for December, 52.5° for January, 54.2° for February, 61.3° for March; at St. George, Charlton County, it is 55° for December, 55.5° for January, 56.6° for February, 62.4° for March.[1] Thus December is the coldest month of the year in the Okefinokee region, and the turning point, when the average temperature begins its gradual ascent, must come, as a rule, in the latter part of the month, shortly after the winter solstice. This turning point, when the average maxi-

1 U. S. Weather Bureau, Climatic summary of the United States, section no. 103—central and eastern Georgia, p. 18, 1932.

mum temperature is in the neighborhood of 63°-64°, and the average minimum temperature about 41°-42°, seemed to coincide approximately with the commencement of the vocal season of *Pseudacris ornata* in Charlton County. However, December of 1935 was the coldest on record in Georgia with the single exception of December of 1917, and precipitation was much below normal.[2] Possibly in ordinary years the vocal season of *P. ornata* may begin as early as November in Charlton County, as it does at Gainesville, Fla.,[3] and in Harrison County, Miss.[4]

After several cool days, the thermometer rose above 70° on January 2, 1936, and hard rain fell in the evening. The unfamiliar note was heard at 10:15 p. m. (65°) in the same place as before, and on the following morning, between 7 a. m. (58°) and 9:50 a. m., in three cypress ponds on Trail Ridge and in wet pine barrens at the very edge of Okefinokee Swamp near Camp Cornelia.

A hard shower in the late afternoon of January 4 stimulated the little minstrels again. During the moonlit evening, with the temperature dropping from 52° (7:22 p. m.) to 46° (9:40 p. m.), I visited the cypress pond where they were calling. A hard and baffling search went on and on, before I could locate one of the frogs, and eventually another, sitting 50° or 60° upright on logs in the water. The first glance revealed them as Holbrook's species. Although on this occasion they kept silent while I was near enough to cast the rays of my electric torch upon them, it was nevertheless with more than ordinary joy that I found myself at least within a few yards of the tintinnabulations of a frog whose vocal habits have been so little studied. One difficulty in locating the individuals was the matter of judging their distance from me; they generally proved to be farther off than I had supposed, from the sound. The chorus was quite intermittent, without evident reason, unless it was the falling temperature that induced the fairly long intervals of silence.

On January 6 the species was heard at intervals through the day: 7:55 a. m. (temp. 66°), just before a shower; 11:55 a. m. (78°), sunny; 3 p. m. (80°), cloudy; and more or less throughout the evening, up to 10 p. m. (64°) and 11:30 p. m. (63°). It was pleasant, on such a balmy winter night, to walk down the lane through the piney woods toward the cypress pond. In the diffuse moonlight the trees took on shadowy shapes, and the dew glistened on the wire-grass. For the time, the piney woods were converted into a sort of dreamland, with a very different aspect from the sunny diurnal landscape. The elfin amphibian pipings at a little distance, and the gentle monotone of an unseen Screech Owl nearer at hand, added a fairy element to the atmosphere. At the grassy edge of the pond a Le Conte's Chorus Frog or two *(Pseudacris n. nigrita)* were giving their hard little rattles, and here and there several Little Chorus Frogs *(Pseudacris ocularis)*, Spring Peepers, and Southern Leopard Frogs *(Rana sphenocephala)* occasionally added their notes.

2 U. S. Weather Bureau, Climatological data, Georgia section, December, 1935, p. 45.

3 Wright and Wright, Handbook of frogs and toads, p. 101, 1933.

4 Allen, Am. Mus. Novit., no. 542, p. 7, 1932.

But *Pseudacris ornata,* represented by perhaps a dozen calling males, provided the dominant voice. In the clear middle of the pond, on logs floating in about a foot of water, I once more found two of the frogs. One of them, perched on the flat top of the log without any concealment, gave a fine exhibition of its vocal behavior. With head pointing upward, back inclined at an angle of 50° from the horizontal, fore limbs extended vertically to the utmost and resting on finger tips rather than palms, dark lateral blotches standing out conspicuously, and vocal sac distended into a little balloon, it made a striking picture (Fig. 1). In the silent intervals between periods of calling,

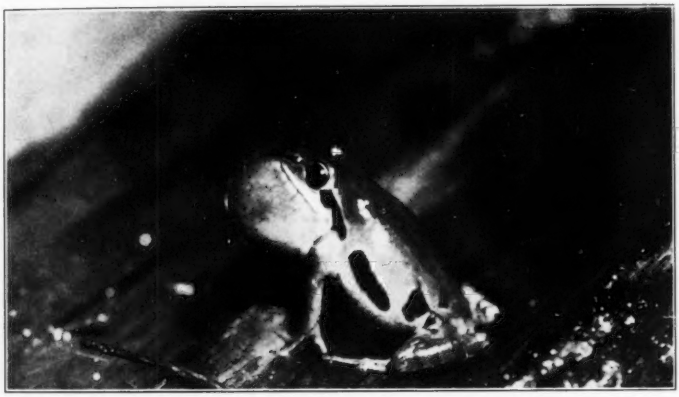

Fig. 1. *Pseudacris ornata,* 31 mm., calling, on a log in a cypress pond. (F. H. No. 441.) Charlton County, Ga. January 6, 1936 (9:07 p. m.).

as well as in the fractional part of a second between each two consecutive notes, the sac remains considerably inflated—about twice the size of the head. The additional air pressure as each note is uttered increases the volume of the sac by about one-fourth. In the frog's normal resting condition, a row of cream-colored spots is evident along the mandible; when it calls, these spots are seen to be on the marginal portion of the inflated vocal sac.

Each day from January 2 to 19 (with the possible exception of January 5) the chorus went on, at temperatures ranging from 41° to 80°. It was heard for the most part during the evening, beginning about sunset, but on warmer days than usual, or after rain, vocal activity was noticed during the daylight hours. Such days were January 3, 6, 7 (80° at 1:08 and 3 p. m.), 11 (69° at 2:55 p. m.), and 15.

Rain during the warm evening of January 14 (68° at 6:12 p. m., 62° at 9:50 p. m.) was followed by generally cloudy weather on January 15, with temperatures higher than the monthly average (62° at 7:50 a. m., 66° at 1:40 p. m., 60° at 6:53 p. m., 54° at 10:23 p. m.). On this date *Pseudacris*

ornata called practically all day and evening. Its voice seemed to carry farther than that of *P. n. nigrita*. With a favoring breeze the chorus was heard up to a distance of about 700 yards. During the early part of the starlit night I spent several hours at the breeding pond. On this occasion one calling male was found in the usual position on a log toward the middle of the pond, but five others were in separate tufts of a tall grass nearer the pond's edge, where they were still surrounded by water averaging perhaps 6 inches deep. Each of these seemed to have a tuft of grass to itself, as if the principle of "territory" were holding here in amphibian life to a certain extent, even if not to such a pronounced degree as it does among birds and mammals. Each was clinging to the grass stems at a distance averaging perhaps an inch or two above the water. (On a previous night one of those on a log had sat with its hind quarters in shallow water.) Here they maintained a more upright position than on the logs, say 70° from the horizontal. A rapid, pulsating compression of the sides accompanied each distension of the vocal sac. When one of the frogs was frightened by my clearing away grass stems about it, it moved to the edge of the tuft, finally plunged into the water, and swam rapidly away beneath the surface.

After a general silence for a time on the part of this species over a certain area, one frog would start calling and soon a number of others would chime in. Evidently an individual's periods of calling may be rather protracted, although the maximum record I happen to have kept is only about 30 seconds. The calls are a rapid succession of single notes uttered at a fairly even rate: *kik-kik-kik*, etc. They are characterized by a *k* sound rather than a *p* sound, such as is heard in the more musical peep of the Spring Peeper. At times there is a sound effect as of double notes—*kikit-kikit-kikit*—but this, I feel convinced, results from the nonsynchronous calling of two or more individuals.

The cypress pond (Fig. 2) in which the studies of the vocal behavior of this species were principally made, covers an acre or so in the midst of pine barrens. It is rather thickly wooded with pond cypress *(Taxodium ascendens)*, while black gum *(Nyssa biflora)* and slash pine *(Pinus elliottii)* occur in smaller quantity. The trees are draped with Spanish moss *(Dendropogon usneoides)*. The middle of the pond is fairly clear of the shrubs that grow abundantly in its borders; these are principally "hoorah-bush" *(Pieris nitida)* and "lather-bush" *(Clethra alnifolia)*. Lesser plants are pipewort *(Eriocaulon)* and *Polygala cymosa*.

Pseudacris ornata seemed in this locality to avoid entirely the branch and creek swamps in which Spring Peepers were calling regularly during the winter. Its breeding habitat *par excellence* was ponds—especially cypress ponds in Charlton County, but a rain-flooded meadow in Ware County and a treeless, marshy pond in Burke County. Le Conte (Proc. Acad. Nat. Sci. Philadelphia, vol. 7, p. 428, 1855) speaks of it as "very common in the pine barren ponds" of Georgia (presumably with special reference to Liberty County). After the breeding season it apparently resorts to the adjacent pine barrens; it was in such an area that I found an adult on June 9, 1929.

Fig. 2. A breeding habitat of *Pseudacris ornata:* a cypress pond 4 miles west of Folkston, Charlton County, Ga. April 29, 1936.

In order to determine a possible relation between the rate of calling in this species and the air temperature (such as is evident in some forms of the *Pseudacris nigrita* group), I secured the following records, all at night. (The term "thermoperiodism"—*cf.* photoperiodism—might be applied to the functional responses of an animal to varying temperatures, and more especially to the relation between the rate of its various activities or functions and the temperature.) On January 4 (temp. about 50°) one of the frogs gave 15 calls in 10 seconds (rate, 90 per minute). On January 5 an individual indoors, after a day of captivity, gave 19 calls in 7 seconds, 41 in 18 seconds, 21 in 7 seconds, and 15 in 5 seconds (room temp. estimated at 60°-65°); this gives a rate varying from 137 to 180 calls per minute. On January 6 (temp. about

66°) a frog twice gave 48 calls in 20 seconds (rate, 144 per minute). On January 10 (temp. 46°) one gave approximately 39 calls in 30 seconds (rate, 78 per minute). On January 15 (temp. about 59°) one gave 60 calls in 30 seconds, 30 calls in 20 seconds, and 30 calls in 15 seconds (rate, 90 to 120 per minute); the lower rate will be disregarded as possibly due to some uneasiness at my presence or movements.

It seems best not to utilize any of the records of January 5, since the conditions were not natural and since the room temperature was only estimated. (In the other cases, if the actual temperature at the time of calling was not known, it was at least approximated by reference to thermometer readings a short time before or after, or both.) The remaining records (of January 4, 6, 10, and 15) were obtained from free individuals at the breeding

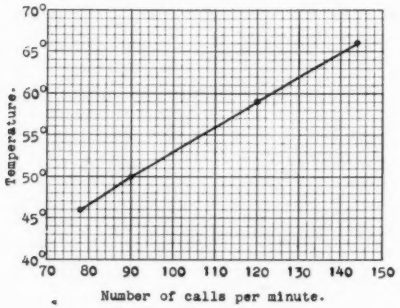

Fig. 3. Relation between the rate of calling in *Pseudacris ornata* and the temperature, in Charlton County, Ga., January, 1936. (For explanation, see pp. 265-266.)

pond. As plotted on the accompanying graph (Fig. 3), they show a definite and fairly uniform relation between the rate of calling and the temperature. It would be reasonable to expect a certain amount of variation according to the physiological condition of the individual (*e. g.*, whether or not it had recently mated, whether hungry or full-fed, etc.). There also remain for consideration humidity, precipitation, barometric pressure, and other meteorological factors, any of which might conceivably affect the rate of calling. There can be no doubt, however, that in general the rate of calling decreases with the temperature. It is unfortunate that many additional records were not secured, especially at more extreme temperatures.

The period from January 20 to February 8 was spent on Floyd's Island, in the central part of Okefinokee Swamp, where *Pseudacris ornata* apparently does not occur, and in the meantime no records of the species were obtainable. From February 8 to March 4, however, I failed to note its voice in the usual area on only 5 or 6 out of the 26 days; there were, during this period, diurnal records on about 5 days and records at dusk or after dark on about 20 days. The temperature recorded at the time of calling ranged from a maximum of about 70° to a minimum of 27°. The latter represents the lowest temperature of which I have any record for the vocal activity of any species of frog. A single hardy individual established this record at 5:15 a. m. on

February 12, and its rate of calling was noticeably slow. One could almost imagine it marooned above a newly formed sheet of ice and whistling to keep its courage up! On only two other days of the entire season (February 10 and 11) was calling recorded at temperatures below 41°. Perhaps the normal minimum temperature for vocal activity is somewhere near this point. (The average minimum temperature for the winter months in this region does not fall below 40°.)

Meanwhile vocal records were secured for a few additional localities in Charlton County: Chesser's Island, February 12 and 14 (first records of the species from within Okefinokee Swamp); Dedge Pond, 2 miles east of Chesser's Island, February 14; Folkston and near vicinity, February 17 and 24 and March 10.

The first week of March practically marked the end of the regular breeding season, or at least the suspension of vocal activity, in this county. Just at this time the average daily temperature was rising above 60°. After March 4 there were only two days on which the Charlton County individuals were definitely noticed in voice. An unusual amount of rain falling pretty steadily on March 9 and 10 even brought out the Spadefoots *(Scaphiopus h. holbrookii)* on the 10th, besides stimulating Holbrook's Chorus Frogs once more. The latter were calling in the usual area at 6:15 a. m. (58°), 9:30 a. m. (59°), and late in the evening (59°). On the same day, at dusk, a large chorus was heard in a wet meadow on the outskirts of Waycross, Ware County. Although March 11 was a clear day, the species was evidently still responding to the stimulus of the previous rainfall by calling at 6:40 p. m. (about 71°), 9:05 p. m. (67°), and 10:18 p. m. (67°).

Apparently the vocal season of *Pseudacris ornata* continues somewhat later in Liberty County, which lies about 60 miles farther north and borders the sea. Here, on Major Le Conte's old stamping ground, I was delighted to detect the voice of a species that he himself had collected in the vicinity a century or so previously *(cf.* Cope, Bull. 34, U. S. Nat. Mus., p. 337, 1889). During the evening of March 22 an individual was heard about 2 miles east of Walthourville, and a chorus about 4 miles west of Riceboro. *Pseudacris n. nigrita* and *Hyla crucifer,* which had exhibited very little vocal activity in Charlton County for a week or more previously, were also in good voice on March 22 along the road from Walthourville to Riceboro. The night was clear, with a temperature of about 60°. Two nights later, during a hard shower at a point 2 or 3 miles southwest of Riceboro, I heard the last *ornata* of the season in voice.

In Figure 4 an attempt is made to show the relation between the vocal activity of *Pseudacris ornata* and the temperature and rainfall in Charlton County during the season of 1935-36. The upper irregular line represents the approximate daily maximum temperature, and the lower irregular line the approximate daily minimum temperature, at my location 4 miles west of Folkston. These data are based upon my own thermometer readings (generally taken about four times per day), supplemented by the daily maxima and minima at three near-by stations of the U. S. Weather Bureau (Waycross, Fargo, and Satilla Forest, near Woodbine—all within a distance of 35 miles

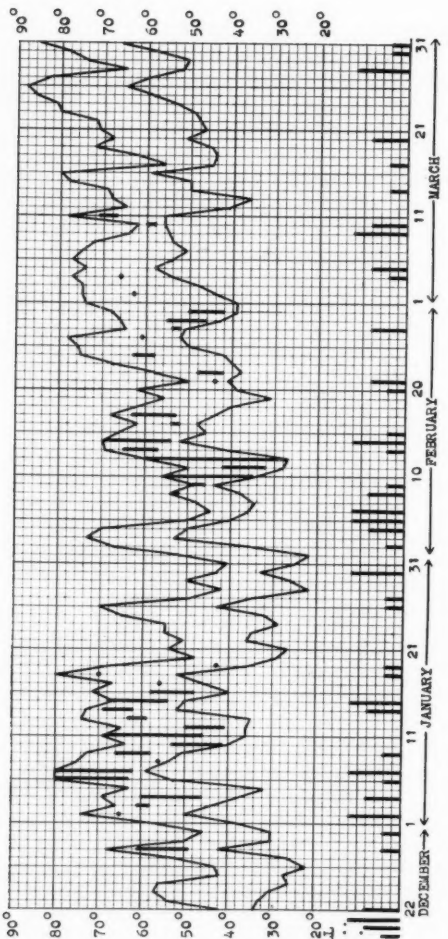

Fig. 4. Relation between the vocal activity of *Pseudacris ornata* and the temperature and rainfall, in Charlton County, Ga., 1935-36. (For explanation, see pp. 267-269.)

from my location). The rainfall data are from my own notes, checked by records from the three stations just mentioned. Both the temperature and the precipitation records have been very kindly furnished by Mr. George W. Mindling, of the U. S. Weather Bureau Office in Atlanta.

The days on which *Pseudacris ornata* was heard calling, as well as the temperatures at which it was heard calling, are indicated by either points or vertical lines within the upper and lower lines representing the extremes of daily temperature. If the species was heard at a single temperature on a given day, the record is represented by a point. If it was heard at two or more temperatures on a given day, the record is represented by a vertical line joining the extremes of these temperatures. In this way both the vocal season and the range of temperatures at which the species was heard calling, may be comprehended almost at a glance. Thus it will be seen that there are only two records at temperatures higher than 71° (both at 80°), and only three at temperatures below 41° (at 35°, 32°, and 27°). The extreme temperatures at which the species was heard are 53° apart; it is doubtful if any other frog of the region engages in vocal activity at such widely varying temperatures. The vocal season in Charlton County practically ends in early March when the average maximum temperature is rising above 72° (the average maximum for March is 73.3° at Waycross, Ware County, and 75.0° at St. George, Charlton County). The only records I obtained after March 11 were in Liberty County. (The complete hiatus in vocal records from January 20 to February 7 is merely due to my absence from the breeding localities of the species, as already explained.)

The vertical lines along the bottom of Figure 4 indicate the relative amount of rainfall day by day, roughly divided into three categories—light, moderate, and heavy. From December 22 to March 1 any rainfall, accompanied by a maximum temperature for the day above 50°, was practically always followed by vocal activity. But even heavy rainfall after March 11 did not seem to stimulate the frog to vocal activity.

A midwinter breeding season must safeguard this species to a very large extent from the attacks of water snakes, which exact a rather heavy toll from those species which breed in late spring and summer. A male frog vociferating at the water's edge at temperatures favorable to prowling snakes exposes itself very decidedly to such enemies.

On April 15, on a grassy flat bordering the St. Mary's River in Camden County, Ga., opposite King's Ferry, Fla., I found a recently but fully transformed individual, measuring 15.5 mm. from snout to vent; the tibia is 8.5. In spirits the dorsal stripes and the lateral blotches are clear and black on a grayish ground; the triangular patch between the eyes is only slightly less distinct; the limbs are distinctly barred; the under parts are whitish.

On April 23 I found three less advanced but larger individuals on the damp, grassy shore of a marshy pond (Fig. 5) in Burke County, Ga., 3 miles north of Thompson's Bridge on Brier Creek. This is the westernmost of a group of several sizable ponds that bear the distinction of having been noticed

Fig. 5. A breeding habitat of *Pseudacris ornata:* the westernmost of Marshman's Ponds, Burke County, Ga., 3 miles north of Thompson's Bridge on Brier Creek. April 23, 1936.

by William Bartram[5] in 1773; they appear to be locally known at present as Marshman's Ponds. The abundant plant growth of the shore includes *Panicum, Viola vittata,* and *Centella repanda.* One of the frogs was under a log, the other two under loose pieces of pine bark. Since they had not even completed transformation, there can be no doubt that they had very recently emerged from this pond. One, with the merest vestige of a tail, measures 19.5 mm. in length from snout to vent. Another, with a 5-mm. tail stub, is 19 mm. in length. The third, with an 11-mm. tail, is 18.5 mm. in length. The tibia in each is 10 mm. In these three preserved specimens the dorsal pattern is rather obscure, and the crossbars on the limbs are poorly defined. In only one are the dorsal stripes and the crown patch very readily distinguishable. In another (the one with the longest tail) the dorsal pattern consists of numerous small spots rather than stripes; possibly this type of coloration belongs to the tadpole stage. The black stripe behind the eye in all three is proportionately broader than in the transformed individual from Camden County.

An adult male (Fig. 6), taken in Charlton County on January 6, was colored in life as follows: dorsum avellaneous in daylight, showing no distinct markings, but paler at night and in the preserved specimen, showing a

5 Manuscript report to Dr. John Fothergill on his travels in the Carolinas, Georgia, and Florida in 1773 and 1774, vol. 1, p. 20. Original in the British Museum Herbarium.

faint V-shaped dusky patch between and behind the eyes and two faint, irregular, and nearly parallel dusky stripes about 2 mm. broad, extending from nape to rump; back slightly rugose; blackish crossbars on dorsal surface of limbs—two on forearm, two on femur, four on tibia; a narrow black stripe along canthus rostralis from tip of snout to eye, slightly expanded at nostril; this stripe continued (and wider) from eye through tympanum to shoulder; area beneath it, except for narrow dusky margin of upper jaw, pale cream, tinged (especially anteriorly) with avellaneous; a black stripe extending from arm insertion along anterior margin of upper arm; sides pale drab, with three blotches (black in daylight, but becoming slaty at night) between axilla and groin; the anterior one elongated, this and the next narrowly bordered with pale cream, the posterior one less black and more or less surrounded with chrome yellow; a series of small chrome yellow spots on anterior surface of femur[6]; ventral surface of femur and tibia dull pinkish flesh color, posterior surface with yellowish spots; tarsus and toes grayish, with about eight narrow blackish crossbars; throat dusky orange (but the vocal sac, when inflated, becomes water-colored); a series of small, elongated creamy spots along mandible; abdomen pale cream, with numerous areolae, increasing in size anteriorly.

Fig. 6. *Pseudacris ornata*, male, 31 mm. (F. H. No. 441.) Charlton County, Ga. January 7, 1936.

Two other adult males from Charlton County have the breast and lower sides well marked with rather small dusky spots; and several among a series from Grady County exhibit similar but fainter spots. A majority from both localities, however, seem to lack the spots.

As indicated above, the dorsal ground color in this species becomes paler at night, and the markings show more distinctly. A similar phenomenon may be observed in various other Hylidae.

The extreme and average measurements of seven adult breeding males from Charlton County are: length from snout to vent, 29.5-32.5 mm. (31.3); tibia, 13.5-15 (13.9); whole hind foot, 20.5-24 (22); intertympanic width, 8-9 (8.8); elbow to tip of third finger, 13-14.5 (13.8); interolecranal extent (distance between elbows when humeri are extended in the same line at right

6 The terms femur and tibia, as ordinarily defined in the dictionaries, apply only to the bones (except in entomology). In the common usage of systematic vertebrate zoology, however, these terms are also applied to the entire limb segments supported by these bones, and the dictionary definitions should be amplified accordingly.

angles to longitudinal axis of body), 18.5-21 (19.6); intergenual extent (distance between knees when femora are extended in the same line at right angles to longitudinal axis of body), 24-27 (25.8). No adult females were encountered during the season, and no particular search was made for eggs.

Eye-shine, which is so pronounced in the Spadefoot *(Scaphiopus)* and in the common toads *(Bufo)*, seems to be only slightly developed in *Pseudacris ornata*.

In addition to the distributional records mentioned in preceding pages, I have a fine series of breeding males taken on Sherwood Plantation, Grady County, Ga., during the first two months of 1936; for these I am much in-

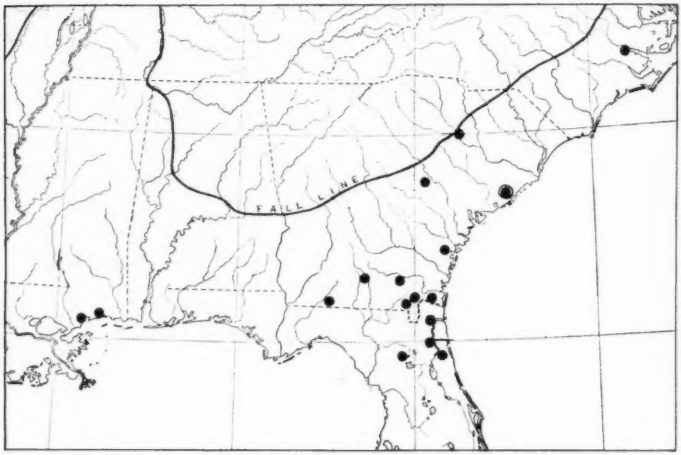

Fig. 7. Distributional map of *Pseudacris ornata*. (The encircled dot represents the type locality.)

debted to Mr. and Mrs. E. V. Komarek. All of the known localities for *Pseudacris ornata* are indicated on the accompanying map (Fig. 7). It will be seen that the great majority of distributional records come from southern Georgia and northeastern Florida. This territory may not represent so much the center of abundance of the species as it does a field where herpetologists have been especially active. All of the records are from the Coastal Plain, the inner boundary of which is indicated on the map by a heavy line. The records from Columbia, S. C., and from Burke County, Ga., make it appear probable that the species will eventually be found more or less throughout the inner portion of the southeastern Coastal Plain up to the Fall Line, as well as along the coast. As yet, records from central and southern Florida seem to be lacking.

SWARTHMORE, PA.

Observations on Bufo cognatus with Special Reference to the Breeding Habits and Eggs[1]

Arthur N. Bragg

The life histories of several North American Anura are not fully known. According to Wright and Wright (1933) the larvae of some twenty-five species need further study and, of these, those of about fifteen species are wholly unknown. Furthermore, the eggs of several species have not been described (Smith, 1934) and many other details of life histories need further study. The method of sex recognition, for example, is known definitely for very few species and the reactions of the sexes to one another's presence during the breeding season is, in many species, only vaguely understood. As Noble and Farris (1929) pointed out, "It does not follow . . . that sex recognition throughout the Salientia is accomplished by use of the same sensory data." Noble (1927) has shown the value of life history studies in working out the phylogeny of the Amphibia. Smith (1934), in separating *Scaphiopus bombifrons* Cope from *S. hammondii* Baird principally upon the characters shown by the larval mouth parts, indicates the value of life histories to those working primarily in taxonomy.

The Great Plains toad, *Bufo cognatus* Say, is one of the species whose habits and life history are incompletely known. According to Wright and Wright (1933) its range extends from North Dakota and eastern Montana southwestward into Mexico and eastern California. Smith (1934) gives a slightly more limited range. The type locality is Prowers County, Col. and numerous records of its presence, often in considerable numbers, are available from Kansas, Texas, Oklahoma, and adjoining states as well as from southeastern California and Mexico. Myers (1930) has shown that this toad is specifically distinct from *B. californicus* (Camp) with which it was formerly subspecifically united. Notes on its habits have been published by Ruthven (1907) and by Strecker (1910). Hartman (1906) found his specimens to have eaten snout beetles and dung beetles. Tanner (1931), however thought that the food of adults might be principally ants with an occasional beetle or beetle larva in addition. Concerning breeding habits, Strecker (1910) says, "They breed in temporary pools as well as permanent springs and small streams and the metamorphosis of the tadpole is said to take less than two weeks." Bragg (1936) gave a description of the tadpole with some notes on the breeding habits of the adults and of the reactions and growth of the early larvae. Strecker (1910) calls attention to the fact that *B. cognatus* may be more diurnal than some other toads, having been seen about, on cloudy days, as late as eleven A. M. and as early as three P. M. Recently, I captured a

1 Contributions of the Zoological Laboratory of the University of Oklahoma No. 155.

small male soon after ten-thirty A. M. on a warm showery day in central Oklahoma (temperature 26.0 degrees, C.).

This paper extends the observations made on *Bufo cognatus* during the spring of 1935 (Bragg, 1936) and includes a description of the eggs. It is based upon field and laboratory studies made mostly during May, 1936 in the vicinity of Norman, Okla. In the field observations made on the night of May 8, I was accompanied and assisted by Dr. J. Teague Self of the University of Oklahoma and by Prof. Roy Jones of the Central State Teachers' College. Through the courtesy of Mr. Albert H. Trowbridge of the University of Oklahoma I am able to publish habit and habitat notes on *Bufo cognatus* taken during his field trips in and about Norman during the springs of 1933, 1934, 1935, and 1936. Dr. A. I. Ortenburger helped with advice and some of the necessary literature. Dr. A. O. Weese aided in the preparation of illustrations. The aid of all of these is gratefully acknowledged.

Habitat

B. cognatus in the Norman area appears to prefer the higher portions of the prairies. I found specimens active in such places from before dusk to well into the night. During the day they rest in temporary, shallow burrows which they dig with the hind feet. The burrows are only a few centimeters deep and of such size that the body of the toad fits into the burrow with the dorsal surface flush with the surface of the ground. Occasionally a toad will be found to have dug deeper but I never found a burrow deep enough to conceal the toad completely. When disturbed the toads often leave the burrows hurriedly and hop away, in which case it is not always evident that the animal has been resting since the burrow is often somewhat hidden by the grass. It is obvious, therefore, that care must be taken in reporting individuals of this species as active during the daylight hours.

During the night hours throughout the warmer portions of the year these toads are very abundant in pastures and grassy fields about Norman. In exceptionally dry hot summers, however, they may be rare. They are not so commonly found in the inhabited portion of the town. Both Mr. Trowbridge and I have repeatedly noted that the toads about the street lights on the campus of the University of Oklahoma are mostly *B. woodhousii*. Recently I liberated ten males and ten females in a garden, well toward the center of the city. Although I have since seen several *B. woodhousii* in this garden I have found but a single *B. cognatus*. On the other hand, I have collected a very few *B. cognatus* on the university campus and recently found two of them, along with several *B. woodhousii*, on a lawn adjacent to a small garden in Norman. This shows that these toads, while preferring uninhabited prairie areas, are not absolutely restricted to them.

Breeding Places

From Mr. Trowbridge's notes and from my own observations it appears that *B. cognatus* in the Norman area breeds only in temporary, rain-formed pools fairly high up on the prairies. They are especially abundant in water-filled

depressions of the type known as "buffalo wallows" (Figs. 1 and 2). Such pools are of various sizes but always very shallow. Under the influence of a hot sun, the evaporation rate from these pools is very high and the water may become warm enough to feel distinctly warm to the touch. At eleven

Fig. 1. Buffalo Wallows in a pasture near Norman, Okla. *Bufo cognatus* produced eggs in these pools in both 1935 and 1936. The dark patches on the ground are the feces of cows pastured here. (Picture taken by A. H. Trowbridge, Dec. 9, 1935.)

A. M., May 9, 1936 the temperature of the water in the large pool shown in the foreground of Fig. 2 was 26.0 degrees C. Two pairs of toads were laying eggs in the pool at this time. A week later, there was not more than half as much water in the pool and it was distinctly warm. Small tadpoles of *B. cognatus* were present in fair abundance. On May 23, the water had completely disappeared from this pool as is shown in Fig. 6. In this instance it is very doubtful that the tadpoles had time to complete their larval cycle, since at the present time (June 12) I have in the laboratory tadpoles which are just completing the formation of the hind legs and which came from eggs laid about a day earlier than those produced in the pool on May 9.

Fig. 6. The same area as that shown in Fig. 2. The dark area in the center is all that remains of the largest pool in this area on May 26, 1936, two weeks after collecting was done.

Sometimes *B. cognatus* breeds along the margins of larger rain-formed pools. I have, however, never found them in muddy ditches nor in the artificially formed muddy water-holes known as "tanks," although *B. woodhousii* readily uses both of these types of places for breeding. Nevertheless, Mr. Trowbridge informs me that he has on rare occasions found calling males in ditches. I quote from Mr. Trowbridge's field notes: "On the night of Apr. 4, 1934 a large congress of *Bufo woodhousii* was observed in the rain-formed pools in the wet meadows of the South Canadian River flood plain about one mile south of the Norman bridge. Although several hundred of individuals were examined, no *B. cognatus* were found. Neither were they heard in this area. On the same night, they were abundant in pools on the high prairie, only four *B. woodhousii* being seen in this locality. No toads of any kind were found in Crystal Lake [a permanent body of water nearby] although

Rana sphenocephala was calling between two and two-thirty A. M." On the night of Apr. 28, 1935, Mr. Trowbridge and I were in the field together. It was a cold misty evening after a hard rain. At Crystal Lake, the only amphibian voice was that of *Acris gryllus*. In the buffalo wallows (Fig. 2) *B. cognatus* males were calling and sevral mated pairs were found. About one-half mile south of the university campus we found an exceptionally large, muddy pool with a maximum depth of about three feet. In this a species of *Scaphiopus* (probably *S. hammondii)* was abundant in the deeper parts of the pool and *B. cognatus,* both males and females, were extremely numerous all about the edges and in the shallower water near shore. Several clasping pairs were observed. A statement from Mr. Trowbridge's notes concerning this pool reads, "*Scaphiopus* must lay its eggs in the deeper parts of the pool, as clasping pairs were very numerous in water nearly knee-deep. *Bufo cognatus* apparently produces its eggs in close to shore." Mr. Trowbridge informs me that he has found breeding collections of *B. cognatus* in temporary

Fig. 2. Buffalo Wallows in another location near Norman. It was here in the pool shown near the center of the picture that many observations were made in 1936. (Photo by the author, May 9, 1936.)

pools within fifty feet of tanks in pastures while in the tanks no *B. cognatus* could be found. I, too, have never found them breeding in tanks, although at the same time they were numerous in buffalo wallows not far away.

A note on the effect of overgrazing on the successful breeding of these toads may be of interest. The location shown in Fig. 1 is a pasture in which during the winter of 1934-35 few cows were kept. It was from pools in this area that the specimens were collected upon which my 1936 paper was based. *Bufo cognatus* eggs laid in these pools in April, 1935 developed normally. During the past winter (1935-36) many cows were pastured here. Fig. 1, from a picture taken on Dec. 9, 1935, shows numerous masses of the feces of the cows scattered about. They were even more numerous in May, 1936 than shown in the figure. On May 8, 1936 these pools were visited. At this time, the water in the pools was yellowish, due to the leaching action of the recent rains on these fecal masses, some of which were in the pools themselves. Two days later, eggs of *B. cognatus* and also others thought to be of *Scaphiopus* sp. were found here in several of the pools. All of these were dead and disintegrating and there were no tadpoles in the pools. The jellies of the *Bufo* eggs teemed with two species of large ciliates and with a species of turbellarian worm, but since the same species of both these types of animals were found, both last year and this, in the jellies of normally developing eggs, they can bear no relation to the death of the eggs. It is thought most probable

that nitrogenous, and possibly other substances derived from the feces and dissolved in the water of the pools caused the death of the eggs. The adults may have some power of discrimination of such water conditions, for there were fewer clutches of eggs produced in these pools during 1936 than in 1935. But, there was much more rain during the latter spring than during the former and fewer toads may have succeeded in breeding because of this.

From the above it is evident that *B. cognatus*, at least in the Norman area, is quite restricted in the selection of breeding places and that successful breeding may be thwarted either by the drying up of the pool before the tadpoles have had time to pass metamorphosis or by contaminated water killing the eggs.

Observations on the Breeding Animals

Almost drought conditions prevailed in Norman during the winter and early spring of 1936. No toads of any kind were seen till the evening of May 1 when, following a light shower, a single *B. cognatus* was seen on the university campus. The next morning another, rather heavy shower fell (1.07 in.) and that evening I found numerous specimens of *B. cognatus* of each sex in the pasture shown in Fig. 1. The rains had not been sufficient to form pools and, accordingly, the toads were not breeding. Later in the evening, a single *B. woodhousii* repeatedly called from a tank in another pasture. A few toads of each of these species called from a fenced-in pool which could not be reached. The rains may have brought the toads from hibernation but evidently few of them could find sufficient water in which to breed.

On May 8 over two and one-half inches of rain fell, filling the depressions on the prairies. Several areas were visited in the evening and careful notes taken concerning the behavior of the toads. The pasture shown in Fig. 1 was the first place visited. Here, before it was completely dark *B. cognatus* males were fairly abundant and some of them were calling. Others were heard in a field nearby. No females were in evidence in or about the pools although one was captured in a road not far away. The males were quite shy, often ceasing to call and hopping away when approached.

In the area shown in Fig. 2, seven pools lay in a space 51 by 32 paces in dimension. Many males of *B. cognatus* and of *Pseudacris* sp.were calling from the sides of the largest pool (forground of Fig.2). A few *Gastrophryne* males were also found in the water at the sides of the pool. A few male *B. cognatus* called from some of the other pools in the area but some pools were entirely silent. Investigation revealed that these silent pools contained only females and that other females occupied the grass among the pools. All of these females were shy and attempted to escape when approached. At the same time, about nine-fifteen, the calling males showed no fear and could be approached closely and even touched without interrupting the call. The first clasping pairs were found in the largest pool at about nine-thirty.

Females were collected and placed very close to calling males. In all cases, neither toad paid the slightest attention to the other; the male merely contin-

ued his raucous rattle, the female hopped quickly away. When, however, the body of the female touched that of the male, he responded promptly by clutching the female. Often the proper clasping position was not obtained at once, in which case the male shifted his position till the axillary grip shown in Fig. 3 was obtained. Males offered in the same way were also eagerly clutched. These were always released within a short time, however, although in no case observed did a male voluntarily release a female.

Fig. 3. A pair of Clasping *Bufo cognatus* showing the typical positions assumed by the animals. Note the markedly lighter color of the female. (Photo by courtesy of J. H. Bragg.)

Cummins (1920) concluded that sight plays little or no role in sex recognition in *Rana pipiens, R. cantabrigensis, Chlorophilus nigritus,* and *Hyla pickeringii.* He observed that males when clasped by others always emit sounds but that females do not do so. Accordingly, he suggested that sex recognition results from the differential behavior of the sexes when clasped. Miller (1909), working with the *Bufo americanus,* expressed the same idea. According to Noble and Farris (1929) a series of factors plays a part in sex recognition in the wood frog, *Rana sylvatica,* the most important of which is the difference in girth or firmness of the body in the two sexes, since that of the female at the breeding season is usually swollen with eggs. After the eggs are laid the male releases the female for exactly the same reason that the males are rejected, namely in response to her lessened girth or firmness. These authors also showed conclusively that voice plays no part in sex recognition in this species.

The *Bufo cognatus* male utters a series of soft chirping sounds when handled or when clasped by other males. The female does not chirp, although characteristically she takes large quantities of air into the lungs and thereby makes the sides of the body puffed out and rigid. In these respects, *B. cognatus* resembles *B. americanus* as described by Miller (1909) and often observed by myself. When a male is clasped he immediately starts chirping and continues this till released, but whether or not the release is due to the chirping is problematical. It may be but the normal response to being held and thus bear no relation to sex recognition. Girth, and especially, firmness of the female's body may play a part but if so it is difficult to explain why a small female is held by a large male.

The position of the male while calling is usually at the water's edge,

facing the pool. A few called from the pool itself and some from dry ground, a foot or two from the water. This is the most advantageous position for securing females entering the pool from the grass.

Ten clasping pairs were collected and taken to the laboratory confined together in a small cloth bag. When removed to a tank of water, two small males had lost their grips on their mates but all of the other pairs were still together. Two clutches of eggs were produced in the tank before nine-thirty A. M. the next day. A large percentage of these subsequently developed into larvae. All of the pairs except two had unclasped and swam about nervously when approached.

One clasping pair (Fig. 3) was removed to another tank in the hope of securing more eggs. Eventually these toads were found separated and the male could not be induced again to clasp the female. The male of this pair differed markedly from the female in color, being very dark. The female was exceptionally light. Twenty-four hours after her release from the male, the female had become much darker than she formerly had been. Whether or not this observation has any significance was not ascertained.

The region shown in Fig. 2 was visited again at eleven A. M. on May 9. Two pairs of toads *(B. cognatus)* were laying in the largest pool but neither eggs nor toads could be found in any of the other pools. Twenty-six hours later a third pair, presumably mated the night before, was producing eggs in the large pool and the clutches of the pairs seen the day before were undisturbed. These three pairs of toads were the only ones of the many about the pools on May 8 which produced eggs at this location. Something of this same thing was noted also in the region shown in Fig. 1, both last year and this. The smaller pools either contained no eggs or but one clutch each. The larger pools often contained three or four clutches but never more than this, despite the fact that often a hundred or more toads were present about the pools the night before. Since too many tadpoles living in the confines of a small pool might be detrimental to the survival of the species, one is tempted to look upon this as an adaptation on the part of the toads. Before coming definitely to such a conclusion, however, many more data than are now available are needed.

Egg deposition is a long process lasting several hours. It is similar, in a general way, to this process in *B. americanus* as outlined by Miller (1909). Typically, two strings of eggs issue from the cloaca of the female, presumably one from each oviduct. Only a few eggs leave the cloacal opening at a time, after which the male contracts the posterior end of his body in such a manner that his cloacal region is brought into close proximity to the eggs. Miller (1909) showed that sperm cells are ejected during this period by the American toad and it is very probable that this is the case with *B. cognatus*. The male maintains this position for about one minute after which his body again relaxes. Thereupon the female crawls forward somewhat carrying the male with her. After a rest of a few minutes the process is repeated. In this manner, the eggs are deposited in two continuous strings wound over and about

the plants on the bottom of the pool and covering a space about three feet in diameter. Miller (1909) described a sort of basket formed by the male *B. americanus* hooking his legs under those of the female as the eggs are laid. This was not observed in *B. cognatus* but it may have occurred, since my observations on the egg-laying process were all made in the field where details were often difficult to make out without disturbing the animals unduely.

Each string of eggs is typically made up of a single row. Occasionally the eggs become crowded together for a short distance in a string in such manner as to distort their shapes somewhat. Such eggs produce normal larvae. Also, the single row of eggs may become double for a short distance (Bragg, 1936). One female under observation produced a single egg string the individual eggs of which were all arranged in a double row. This is exceptional.

In my earlier article (1936) the following rather ambiguous statement occurs (p. 15), "Usually a single row of eggs is produced but occasionally a string will be double." The idea that I intended to convey was that the individual eggs within each egg string were typically arranged in a single row although occasionally in a double row. Thus, there is no disagreement between the observations made in 1935 and those made in 1936.

Description of the Eggs

The egg envelopes were studied by the following procedure: small portions of an egg string were cut off with scissors and placed for four and a half hours into a vial containing Schneider's acetic carmine. They were then removed, washed in water, and examined with low power lenses by reflected light. This method was valuable for the study of the finer structural details of the gelatinous envelopes.

Three membranes were demonstrated about the eggs: (1) a very thin one closely applied to the surface of each egg (vitelline membrane ?) which could

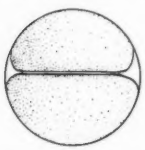

Fig. 4. Two-cell Stage of a *Bufo cognatus* Embryo Showing the Vitalline Membrane.

be seen only after cleavage had occurred, at the ends of the cleavage furrows (see Fig. 4); (2) an inner gelatinous envelope about each egg; and (3) a tougher, continuous, gelatinous tube enclosing all other materials and extending uninterruptedly throughout the entire length of each egg string. (See Fig. 5.) Both types of gelatinous envelopes appeared laminated when stained; the laminae of the individual egg envelopes gave the appearance of being closely pressed together about midway between any two adjacent eggs; the laminae of the outer tube appeared to extend lengthwise along the tube as shown in the figure.

The individual eggs are small and have an average diameter of 1.18 mm. The egg envelopes are about 0.22 mm. in thickness. The outer tube measures about 2.05 mm. at its widest point (i.e., across the diameter of an egg) but is somewhat larger (2.66 mm.) when the eggs are arranged in a double row. At its narrowest point (i.e., between eggs) the tube is about 1.72 mm. in diameter. In color, each egg is black at the animal pole, shading very gradually to white in the vegetal region. The pigment is distributed over much of the egg, however, so that the general appearance of the egg is quite dark. As is so common with amphibian eggs, the dark pole tends to rotate upward when free to do so.

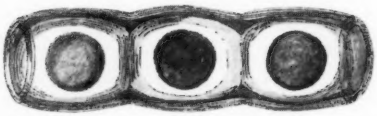

Fig. 5. The jelly envelopes about the eggs of *Bufo cognatus* as seen when stained as described in the text. (x8.) (Drawing by courtesy of Mr. O'Reilly Sandoz.)

One clutch of eggs produced on May 9 in the pool shown in the foreground of Fig. 2 was collected on May 10 for counting. At this time the jellies already had begun to soften and the embryos were practically all in the closed neural tube stage. Because of the minuteness of the embryo and also because the egg strings were so easily broken, it is impossible to be certain that all of the embryos were collected even though every attempt was made to do so. The number of embryos collected was 19,617. Since this clutch appeared to be of average size, it may be assumed that the number of eggs produced in one clutch by *Bufo cognatus* is about 20,000.

Eggs laid in the laboratory were cultured as described in my earlier paper (1936) and some notes taken on the method of hatching. Embryos which happen to lie at or near the ends of an egg string often slip from the tube and continue their development in the outside medium. Just how the embryo emerges from the inner envelope in these cases was not observed. Those embryos which do not fall from the ends of the tube emerge through holes which appear in the jellies just prior to hatching. As the embryos develop, the jellies surrounding them become noticeably softer and the cavity in which each embryo lies becomes larger. Gradually an opening appears connecting this cavity with the outside water. How these openings are formed was not ascertained but it is thought probable that the tadpole possesses a frontal gland such as that described by Noble (1926) for some other Amphibia. If so, this presumably produces a substance which dissolves the jellies.

Once the openings are formed, the larvae emerge slowly, being carried head foremost into the water by the action of the external cilia. This same action tends to take the larvae away from the vicinity of the jellies in the majority of cases so that the larvae in a glass dish tend to become aggregated, soon after hatching, about the sides of the container to which they adhere by means of the adhesive organ. Any larvae which fail to move away from the jellies after hatching may be injured by disintegration products of unfertile

eggs. Such products are very harmful to young larvae, often causing them to develop without heads, with swollen abdomens, or with other abnormalities. All larvae injured in this way which I have seen died sooner or later, although a few which were visibly injured lived for several days when transferred to a bowl of clear water.

Spiral Swimming of Larvae

In my article of 1936, the spiral swimming of *B. cognatus* larvae was noted. More larvae were found to turn to the left as they swam than to the right. This year's lot of tadpoles was also studied from this point of view.

When an individual tadpole was placed in a finger bowl of tap water and stimulated by a light touch with a needle, there was considerable variation in the direction of spiralling both by different individuals and by the same individual at different times (Table 1). When a bowl containing a culture of tadpoles was watched closely and individuals observed as they started to swim spontaneously, the following was the result: out of 104 readings, 45 spiralled to the right, 50 to the left, and 9 started in one direction and shifted to the other while still swimming. Of these nine, five changed from right to left, three from left to right, and one started to the left, shifted to the right, and changed again to the left.

These figures seem to indicate a considerable variability in the direction of spiralling but with a slightly greater tendency to turn to the left. This is more noticeable in individuals which are artificially stimulated than in those that move spontaneously. It seemed to make no difference upon which side the animal was stimulated.

Table 1. Direction in which individual tadpoles of *B. cognatus* turned when each was stimulated separately with a dissection needle.

	Individual No.	Right	Left	Mixed	Total times stimulated
	1	1	9	0	10
	2	4	4	0	8
	3	4	6	0	10
	4	4	6	0	10
	5	2	8	0	10
	6	2	6	LRL, LR, RLR	11
	7	4	4	LR, LR	10
	8	0	8	LR, LR	10
	9	3	7	RL	11
	10	1	3	LR, LRL, RL LR, LRL	9
Total		25	61	13	99

Summary

The Great Plains toad, *Bufo cognatus* Say, typically lives on the higher portions of the uninhabitabed prairies, being more rarely found in inhabited areas. During the day it rests in shallow burrows from which it comes forth at night to feed and to breed.

In central Oklahoma, its breeding is almost wholly restricted to shallow temporary rain-formed pools. This habit results in many clutches of eggs being lost through the pool's drying up too soon for the tadpoles to complete metamorphosis and also through contamination of the water of the pools. A rain of an inch or more brings hundreds of males to the breeding sites, at least during April and May. Males may begin calling during the twilight hours but females do not join them till later in the evening. Males usually call from the edges of the pools, and females sometimes congregate in other, nearby pools before joining the males.

Sight plays little or no part in sex recognition; a calling male clutches any toad which happens to touch him. Males when clasped or handled "protest" by chirping. Females often make the same respiratory movements but do not chirp. Females, once clasped, are retained tenaciously; males are soon released. Amplexation is axillary and a male in the wrong position works till he obtains the correct one.

Egg laying is a long process. Amplexation occurs at night but the eggs are often not all laid till the afternoon of the next day. Typically, the eggs are produced in two long strings wound about in the space of two or three feet at the bottom of the pool. The eggs, and presumably the sperm, are emitted at intervals, a few at a time. Within each string, the eggs are usually arranged in single file; however some strings of eggs may be arranged wholly or partially in a double row. One female produced a string of eggs all arranged in a double row.

The eggs are small, heavily pigmented, and very numerous. Each is enclosed in two separate membranes: (1) a thin vitalline membrane closely applied to its surface, and (2) a laminated gelatinous capsule. The capsules of each egg string are enclosed by a continuous, tough, gelatinous, laminated tube which has a greater diameter across the equators of the eggs than elsewhere.

Tadpoles hatch by passing through jagged holes one of which appears opposite each in the gelatinous envelopes. Upon hatching the larva moves slowly away from the jellies by means of its cilia and finally attaches to some object by means of the adhesive organ. Later, when it begins locomotion by muscular action, it swims in a spiral, turning either to the right or to the left. In some two hundred determined, there was a slight tendency to spiral more to the left although some individuals seemed to turn in one way as often as in the other.

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Ecological Observations on Amphibians and Reptiles Collected in Southeastern Oklahoma During the Summer of 1934[1]

Albert H. Trowbridge

Introduction

Throughout the months of June, July and August, 1934, a field party composed of Mr. and Mrs. Mark Holcomb, Mr. and Mrs. H. L. Whitaker and the writer, collected vertebrate animals in several localities of LeFlore and McCurtain Counties in southeastern Oklahoma (Fig. 1). More than 2,000 amphibians and reptiles, 20 gallons of fish and several hundred mammals were taken. This paper deals with the amphibians and reptiles. Mr. Whitaker plans to publish on the mammals in the near future.

The work was aided by a grant from Dr. Howard Atwood Kelly, of Baltimore, Maryland, and by loan of equipment from the University of Oklahoma Biological Survey. The field identifications of the writer have been checked by several individuals. Dr. A. I. Ortenburger and Mr. Patrick Nuhfer have checked the snakes and lizards; Dr. K. P. Schmidt the caudate amphibia and turtles; and Mrs. H. T. Gaige the Anura. All members of the party are mutually responsible for the successful results of the expedition and especial acknowledgment is due Mr. Lee Vinson, a resident of Zoe, LeFlore County, for his guidance and aid in collecting on Rich Mountain. All specimens are deposited in the University of Oklahoma Museum of Zoology.

Ortenburger (1927) listed all the amphibians and reptiles then known to occur in Oklahoma, including specimens gathered in both LeFlore and McCurtain Counties. Two years later (1929) he published a list of amphibians collected in southeastern Oklahoma and southwestern Arkansas. He published a key to the snakes of Oklahoma (1927a) and in revised form to include the lizards (1930). More recently Burt (1935) has extended the distribution of certain forms to include LeFlore County.

Dunn and Heinze (1933) recorded three species of *Plethodon* taken on Rich Mountain a few miles east of Page, LeFlore County. Many years earlier Cope (1869) described *Eurycea multiplicata* from the Red River, Oklahoma. Presumably his material came from southeastern McCurtain County.

The present paper adds no new reptiles to the state list but the range of *Anolis carolinensis* is extended northward into central LeFlore County, the northern limit of the range within the state of *Natrix f. confluens* is fairly well defined, and miscellaneous notes on the natural history of the several

[1] Contribution from the Zoological Laboratory of the University of Oklahoma, Second series, No. 159.

species are presented. Seven species of amphibia new to the state have been reported (Trowbridge, 1937), and the range of *Bufo punctatus* is extended to include northeastern McCurtain County. An attempt is also made to correlate the effects of the unusual climatic conditions with the numbers of individuals and the species taken. Included in the list of species are records from the literature. This paper therefore gives a complete summary of the species of amphibians and reptiles known to occur in the two counties.

General Physiography of the Region

Physiographically the region studied is divided by Bruner (1931) into two provinces, the *Ouachita Mountain Region* and the *Red River Region*. Of the former Bruner writes,

> The Ouachitas form the largest mountainous area in the state. . . and form the most rugged region of Oklahoma. The resistant peaks of Jackfork limestone reach a maximum elevation of 3,000 feet above sea level. The greatest extreme of elevation is that of Rich Mountain which towers 2.000 feet above the valley floor. Oak forests dominate but admixtures of pine are common on rocky slopes and in the extreme southeast the pines completely occupy certain areas.

> The Red River Region extends 170 miles along the southeastern border of the state. The greatest width is 45 miles, but most of it is much narrower. Here the lower Cretaceous sands, shales and limestones have weathered into deep fertile soils. Oak and pine are common in the eastern part, while savannah occurs in the west. Owing to the fertility of the soil and favorable moisture relations much of the land is under cultivation.

General Vegetation

The vegetation of both LeFlore and McCurtain Counties is a direct expression of the physiographic and climatic conditions. As a whole, the region is, or has been, heavily wooded, the uplands with pine *(Pinus echinata)* and oak (several species); the bottomlands along the streams with sweet gum *(Liquidambar styraciflua)*, black gum *(Nyssa sylvatica)*, American elm *(Ulmus americana)*, southern hackberry *(Celtis laevigata* Wild.), rough-leaved hackberry *(Celtis occidentalis crassifolia)*, red birch *(Betula nigra)*, sycamore *(Platanus occidentalis)* and many others.

The Little River, Mountain Fork River, and Red River bottomlands southeast of Broken Bow, McCurtain County, are occupied dominantly by bald cypress *(Taxodium distichum)*, sweet gum and sycamore. The flat-lands bordering Mountain Fork are covered with a mixed pine-oak forest, now being lumbered for the second time. For full details of plant distribution of the area see Bruner (1931).

Climate and Effects of the Drought

Practically the entire state felt the unusual climatic conditions imposed by the drought of 1934, but the lack of rainfall was nowhere more noticeable than in the two counties under consideration. Normally, the annual precipitation of the southern half of LeFlore and all of McCurtain County is in the neighborhood of 45 inches (Bruner, 1931, Martin, 1934), a great part of which falls during the growing season—from April to October inclusive

(Bruner, 1931, Martin, 1934, Knobel, Boatwright and Boatwright, 1936). During June, July and August, 1934, there were only two or three insignificant showers with less than .8 of an inch of rain. There was not much more during the preceding spring months.

As the amount of precipitation is the most important environmental factor in the distribution of Oklahoma plant formations (Bruner, 1931) and consequently one of the most important to their well being, the effect of an extended drought could be expected to appear early in the mesophytic forests. Such proved to be the case in the localities where most of the collecting was done. By the end of the first week in July the leaves of many of the oaks were withered and brown and many of the smaller pines were apparently dying. By the end of July the upland forests were brown in general aspect, due to the very many dead leaves of a majority of the smaller and some of the larger oaks and many of the pines. The trees along the water courses were, of course, not so seriously affected. Mediocre crops were obtained only in the most favored bottoms, while the mast crop of acorns and bitter hickory nuts was a total loss.

Almost all of the smaller streams were entirely dry by the first of July and the larger streams such as Black Fork Creek and Mountain Fork River were lower than the old residents had ever seen them. Springs which had been flowing at capacity for many years were totally dry and others ran for only a few hours at night and in the early morning. The swamps southeast of Broken Bow were all dry, with the exception of a few of the larger and deeper sloughs, and the cypress knees were practically all on dry ground.

The reactions of the animal life as a whole to drought conditions were direct and vigorous. The breeding of the smaller mammals was retarded (Whitaker); the fishes were concentrated in the deeper pools of the smaller streams and subject to attack by fish-eating birds (Trowbridge and Whitaker, 1934), and also to the ravages of an aggregated reptile population. As the mountain branches were reduced to occasional small spring holes, the salamanders *(Desmognathus)* were also aggregated in large numbers. The dryness of the soil must have caused such forms as *Plethodon* and *Eurycea* to aestivate at some distance below the surface of the ground. Aquatic invertebrates suffered, also, as the breeding pools were dry by the early part of the summer. Only one stone fly *(Plecoptera)* and two May flies *(Ephemerida)* were taken. Mosquitoes, which normally are very numerous and responsible for the high indigenous malarial infection in southeastern McCurtain County, were rarely seen. Mountain Fork River was so low in many places that vast beds of mussels were completely destroyed.

Domestic animals (hogs and cattle) of the open range areas of both LeFlore and McCurtain Counties suffered severely. The shortage of forage weakened the resistance of the cattle, and the low humidity and high temperatures, coupled with the drying up of the smaller streams and water holes, caused many hogs to die. It was not uncommon, especially in southeastern McCurtain County, to be led to the carcass of a dead pig by a circling horde of turkey buzzards.

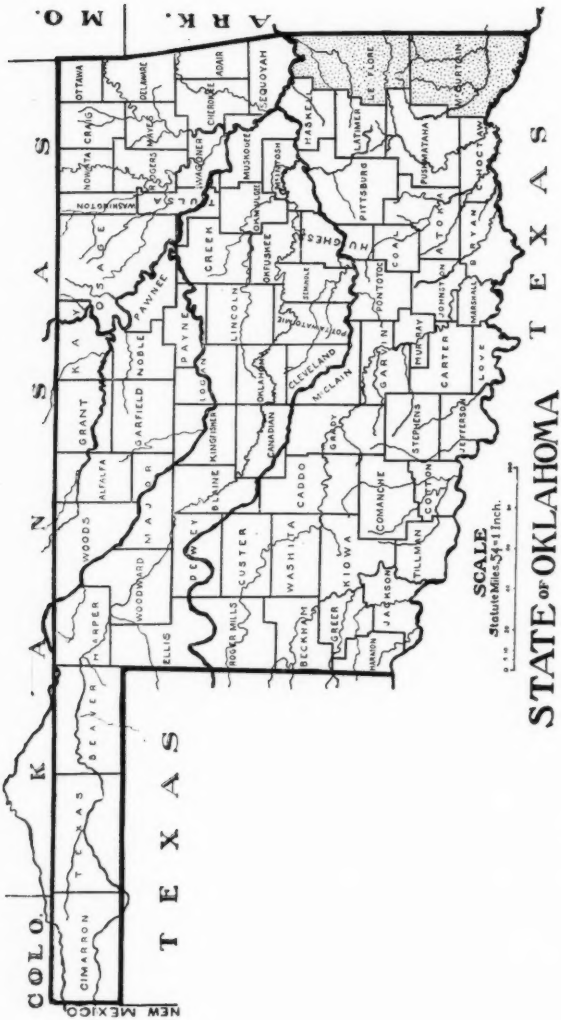

Fig. 1. Sketch map showing the location of LeFlore and McCurtain Counties, Okla.

Area Studied

Due to the large area included by LeFlore and McCurtain Counties it was not possible to work thoroughly the entire area. Consequently four base camps were established and the country explored in some detail within a radius of five to ten miles.

Camp I. June 6-11, inclusive. On the banks of the Poteau River, opposite the mouth of Conser Creek, 6.5 miles west of Heavener, Le Flore County. The surrounding country is well populated and much of the land is under cultivation. Most of the collecting was done along the margins of the cultivated fields and along the Poteau River and its tributaries. The general elevation ranges from 600-900 feet. For details of soil types and map see Knobel, Boatwright and Boatwright (1936).

Camp II. June 12-July 5, inclusive. In deciduous forest on the banks of Black Fork Creek near the low water bridge at the foot of Freeman Hole, 1.5 miles east of Zoe, LeFlore County. The country is not so heavily populated as it is farther north and only the lower areas with suitable soil are under cultivation. As a whole, the country is rugged and broken with numerous rough rocky ridges and small hills. Ortenburger (1928) has characterized the chief plant communities of this locality and the soil structure is discussed by Knobel, Boatwright and Boatwright *(loc. cit.)*.

Camp IIa. June 23-26, inclusive. This subcamp was located on the northwest side of Rich Mountain near a small spring-fed tributary of Big Cedar Creek of the Kiamichi drainage. The divide between this drainage and that of the Arkansas River was about a mile from camp where the headwaters of Bushy Creek began and flowed northward to Big Creek, a tributary of Black Fork Creek. Most of the collecting was done along the spring-fed streams and waterholes between Rich and Spring Mountains near the Pine Valley-Page railroad. The camp was about six miles west of Page, LeFlore County. The elevation ranges from 900 to 2,600 feet.

Camp III. July 5-24, inclusive. This camp was two miles southwest of Smithville, McCurtain County, on a bluff overlooking Mountain Fork River one-quarter mile south of the mouth of Eagle Creek. The surrounding country is a mixture of cultivated fields and forested areas and the general elevation is in the neighborhood of 800 feet. The entire area is somewhat south of the Kiamichi Range.

Camp IV. July 25-August 18, inclusive. The camp was located 14 miles southeast of Broken Bow, McCurtain County, on Mountain Fork River. The region is generally forested, the bottoms with cypress, sweet gum, sycamore, etc., while the flat lands bordering the river and extending several miles westward are dominantly pine and oaks, several species). A little of the bottom land is under cultivation, but stock raising and lumbering are more important industries. The country is lightly populated and has a general elevation of 450-500 feet.

List of Species and Remarks

SALAMANDERS

1. *Triturus viridescens symmetrica* (Harlan)

This colorful little newt was taken only from under logs and limbs in the bottomlands 13.5 miles southeast of Broken Bow, McCurtain County. In all cases the individuals were partially embedded in the moist, dark soil. About twenty specimens were taken, but the species is not abundant. Ortenburger (1927) refers material of what is probably the same form to *T. v. louisianae* (Wolferstorff). Stejneger and Barbour (1933) do not recognize this subspecies, but Smith (1934) is inclined to accept it. For the present we are using the name *symmetrica*, recognizing the fact that the niceties of taxonomy may ultimately result in a return to the name used by Ortenburger (1927).

2. *Ambystoma opacum* (Gravenhorst)

Four specimens of the marbled salamander were taken from under logs in the bottoms along Mountain Fork River, 13.5 miles southeast of Broken Bow. It is apparently a rare species in Oklahoma.

3. *Ambystoma maculatum* (Shaw)

Only one specimen of this species was taken. It was embedded in the damp soil under a log in the same general area where the *A. opacum* were found. This species, also, is apparently rare in Oklahoma. In any event both of these salamanders are nearing the extreme western limit of their range.

4. *Plethodon cinereus* (Green)*[2]

A red-backed specimen of this species was taken on Rich Mountain east of Page, LeFlore County, by Dunn and Heinze (1933). We took no members of this genus in 1934.

5. *Plethodon glutinosus* (Green)*

Dunn and Heinze (1933) recorded a single specimen of this species taken on the north side of Rich Mountain, east of Page, LeFlore County.

6. *Plethodon oucahitae* Dunn and Heinze, 1933*

The type locality of this species is designated in Arkansas by Dunn and Heinze (1933). They secured specimens of this species from the north side of Rich Mountain, east of Page, LeFlore County.

As indicated above, we took neither *Plethodon* nor *Eurycea* during 1934. Due to the dryness of the soil high up on the sides of the mountains it may be possible that these genera went into aestivation. At least, we made special efforts to find them, all to no avail.

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2 Species marked with an asterisk were not taken during the summer but are reported in the literature cited in connection with them.

7. *Eurycea melanopleura* (Cope)*

The only record of this species is that given by Ortenburger (1929) who obtained specimens in LeFlore County in the vicinity of Spring Mountain.

8. *Eurycea multiplicata* (Cope)*

Cope (1869) described this species from the Red River, in eastern Oklahoma. As indicated above, the type locality is probably in McCurtain County. The writer is acquainted with no recent records of this species for Oklahoma, except that of Ortenburger (1929a) for Delaware County.

9. *Desmognathus fuscus brimelyorum* (Stejneger)

Several hundreds of these salamanders were taken. As noted above they were aggregated in large numbers in the few pools of the spring-fed branches and smaller stream courses. The first specimens were taken four miles east of Page, LeFlore County, June 4, from a series of small spring-fed pools high on the north side of Black Fork Mountain. The water was clear and cool, the bottom gravelly and covered with dead leaves. Another series was taken June 23-26 from a small, spring-fed stream on Spring Mountain about five miles west of Page. Mrs. Holcomb noted that the larger individuals were generally found under flat stones or buried in the gravel, whereas the smaller ones were in the crevices or between smaller stones. Numerous specimens were taken from a spring near Eagle Fork Creek, two miles west of Smithville, McCurtain County, and still others 12 miles southeast of Broken Bow. Here they were very numerous in the black mud under sticks and stones of small spring-fed branches. This form was the most common salamander encountered during the summer.

10. *Siren lacertina* Linné

A single specimen of the mud eel was taken from the black ooze of a spring run 12 miles southeast of Broken Bow. It has been considered in some detail elsewhere (Trowbridge, 1937).

ANURA

11. *Bufo americanus americanus* Holbrook

The American toad is common throughout the areas in which collecting was done. Specimens were taken at Camps I, II, IIa, III, and IV. They became active just before dark and their high mournful trill could be heard throughout the night from the edges of the rivers and pools. A number of specimens were obtained from the garbage pits at the several camps, and on July 21, eight individuals were taken from a dry, abandoned well in an open pasture about 2.5 miles south of Smithville.

12. *Bufo punctatus* Baird and Girard

This rare little toad has been reported from Comanche County (Ortenburger, 1927) and from Major County (Burt, 1935). Both these counties are in the western part of the state. A single specimen was taken July 21, from under a board in an extremely dry situation, two miles southwest of

Smithville. The ground color of the back was tan with many fine reddish-orange tubercles. A fine cream-colored, mid-dorsal line passed from near the tip of the snout to the posterior end of the urostyle. There were five large, low, dark, brown warts on each side of this line. The belly was yellowish-white, faintly spotted with black and the ventral skin was almost transparent. This record apparently extends the range of the species several hundred miles eastward. Mrs. Gaige has not seen this specimen.

13. *Acris gryllus* (LeConte)

Specimens of the cricket frog were collected or seen at every camp. They were fairly common around all streams and pools, but not nearly so abundant as they are in the vicinity of Norman and other parts of central Oklahoma.

14. *Pseudacris triseriata* Stejneger and Barbour

A single specimen taken from under a log 12 miles southeast of Broken Bow is referred to this species. It has been considered in more detail elsewhere (Trowbridge, 1937).

15. *Hyla cinerea cinerea* (Schneider)

No specimens of this species were taken, but they were heard nightly along Mountain Fork River below Camp IV. They are rather common in the region and occur in the Little River bottoms. Trowbridge (1937) recorded a specimen taken by Dr. J. T. Self from Broken Bow Lake. Doctor Self informs me that they were very common here during August, 1933.

16. *Hyla crucifer* Wied

The spring peeper is uncommon throughout southeastern Oklahoma. Three specimens were taken in the vicinity of Camp IV and are discussed by Trowbridge (1937).

17. *Hyla versicolor versicolor* (Le Conte)

These frogs are called raintoads by the residents of the area where they were taken, due to their habits of calling lustily during and following summer rains. Numerous specimens were secured from Camps II, III, and IV. On June 22, the Holcombs found one sitting in the sunshine on a board over a well in a farmyard, six miles west of Zoe. Many specimens were taken in the woods along Mountain Fork River and Eagle Fork Creek, two miles southwest of Smithville. They were also abundant in the bottoms 13.5 miles southeast of Broken Bow. The majority of the specimens taken were found in the crotches of trees or under bark. The greater part of our specimens were captured during the daytime.

18. *Rana catesbeiana* Shaw

The bullfrog is common along all of the larger streams. Specimens were secured at Camps I, II, III, and IV. Large egg masses of this form in the late neural tube stage were found in a set-back from the Poteau River, six miles west of Heavener, June 7.

19. *Rana clamitans* Latreille

While individuals of this species are common, they are not as numerous as *R. sphenocephala*. Good series were taken from Camps I, II, III, and IV.

20. *Rana palustris* Le Conte

Specimens of the pickerel frog were taken only in McCurtain County. A good series was obtained along Eagle Fork Creek two miles southwest of Smithville and from along Mountain Fork in the same general vicinity. In this locality they were most often sitting in the brush a few feet from the water's edge. In the vicinity of Camp IV they were more commonly found under logs and around drifts piles in the bottoms. This was probably due to the drying up of the smaller streams.

21. *Rana sphenocephala* (Cope)

The southern leopard frog is the commonest anuran in southeastern Oklahoma. Specimens were taken in large numbers from all camps. Burt (1935) prefers to designate the leopard frog of this area *R. pipiens*. Our specimens differ considerably from typical *pipiens* in having a longer head, more pointed snout, and smaller, rounder dark dorsal blotches.

22. *Gastrophryne carolinensis* (Holbrook)

Four specimens of the narrow mouth toad were taken in McCurtain County. On July 21, a single individual was found on the banks of a small tributary of Mountain Fork where it flowed through thickly grown meadow 2.5 miles southwest of Smithville. Three others were taken from under boards or logs along a spring-fed run 12 miles southeast of Broken Bow.

LIZARDS

23. *Anolis carolinensis* Voight

The only previous record of this species is that of Ortenburger (1927) who collected ten specimens in McCurtain County in 1925. A large number of specimens were taken from Camps II, IIa, III, and IV. The first specimen was shot June 17 while it was running along the edge of a deep rocky gully at the foot of Black Fork Mountain, four miles east of Page, LeFlore County. Other specimens were taken in LeFlore County from 2.5 miles northwest of Stapp, 3.5 miles southwest of Stapp on the road to Winding Stair Mountain tower, and 3.5 miles northeast of Page. The Holcombs took one on the east side of Freeman Hole, about two miles east of Zoe that was observed to jump from tree to tree.

This species was particularly abundant in the general vicinity of Smithville. Many specimens were taken in the wooded areas along Eagle Fork Creek and others below the junction of Mountain Fork River and Boktukalo Creek near the Narrows. The majority of the specimens were found on small trees, particularly those with light, mottled bark, such as the sycamore.

24. *Crotophytus collaris collaris* (Say)

Although the type locality of this species is at the mouth of the Verdigris

River near its union with the Arkansas River in Muskogee County, it is not at all common in the areas studied. Eleven specimens were obtained in LeFlore County and none in McCurtain County. Ortenburger (1927) recorded this form from McCurtain County. Spot records are: 10.8 miles west of Heavener on Conser Road; 13.8 miles west of Heavener on Conser Road; five miles west of Heavener; seven miles southwest of Heavener; .5 mile west of Zoe in front of Zoe-Stapp school; 1.5 miles north of Zoe on small mountain; 6.2 miles north of Stapp; and three miles north of Zoe on the side of Walker Mountain near Kelly Hollow.

This form was generally found among the rocks on the hills covered with scrub oak, but one was shot shortly after noon from the top of a fence post where he was sleeping in the sun. The scarcity of this species can be explained on the assumption that it nears the eastern and southern limits of its range in this section of the state.

25. *Sceloperus undulatus undulatus* (Latreille)

The pine-lizard was taken from all camps and is widely distributed throughout the area. It was generally found in the thinly wooded areas and about the edges of the forests. Many were taken from trees. This species extends well up on the sides of Rich Mountain and was seen and taken high on Black Fork Mountain. It is one of the most common reptiles of the region.

26. *Cnemidophorus sexlineatus sexlineatus* (Linné)

The swift is equally abundant and as widely distributed as *Sceloperus,* but it is more a form of the open. It was generally prevalent in the weeds along the roads, in open fields, along the fence rows, and along the edges and in the open glades of the forests. Specimens were taken from all camps.

27. *Leiolopisma laterale* (Say)

Specimens of this little lizard were taken from all camps. Although *Leiolopisma* is common, not so many were taken as might be expected. This was due to the secretive habits. It was most often found in forested areas under logs and debris and was particularly common among dead leaves of the scrub oak communities. Burt (1935) reported specimens collected north of Page as *Leiolopisma unicolor* (Harlan). There is little doubt but that a single species is represented in the area, although the writer has not seen Doctor Burt's material.

28. *Eumeces anthracinus* (Baird)

Four examples of this skink were taken, all from under logs or from trees, 14 miles southeast of Broken Bow.

29. *Eumeces fasciatus* (Linné)

The blue tailed skink was rather common and specimens were taken from the following localities: LeFlore County: two miles north of Zoe; 1.5 miles east of Zoe, and within the limits of Camp II. McCurtain County: two miles southwest of Smithville and 14 miles southeast of Broken Bow.

30. *Eumeces laticeps* (Schneider)

This species was the only member of the genus taken at all camps. It is widely and commonly distributed throughout the area investigated.

31. *Eumeces obsoletus* (Baird and Girard)

Two examples of this form were secured in McCurtain County—one two miles southwest of Smithville, and another 14 miles southeast of Broken Bow.

In general, all members of the genus appear to have the same habits. All are forest forms which are elusive and hard to capture. We obtained specimens from under logs, from as high as 25 feet from the ground in trees, from hollow trees, in pine-oak forest and in bottomland forest.

32. *Ophisaurus ventralis* (Linné)

Although no specimens of this lizard have been reported in the literature and none were taken during 1934; there is a single specimen of the glass-snake from southeastern Oklahoma in the University of Oklahoma Museum of Zoology. It was taken June, 1931, in the vicinity of Idabel, McCurtain County.

Snakes

33. *Carphophis amoena vermis* (Kennicott)*

This species has been reported for LeFlore County by Ortenburger (1929). It is probable that it ranges into McCurtain County.

34. *Diadophis punctatus arnyi* (Kennicott)

Four specimens of this little snake were taken from under rocks on Spring Mountain in LeFlore County. None were taken at any other locality. It is probable that their apparent rarity was due to the season. I have noticed that this species is very common under stones on the prairies during the spring months, but with the coming of summer they are seldom found. The same holds true for *Tantilla* and *Sonora*. It remains a question why we did not find the ring-neck snake in southeastern McCurtain County, especially in the bottoms.

35. *Heterodon contortrix* (Linné)

Only two examples of the hog-nosed snake were taken—a dead, dried specimen six miles north of Stapp, the other a beautifully colored male from two miles southwest of Smithville. This form was undeniably rare during 1934. Acording to many residents of the region, it is generally very common. It may be that the lack of rain and high temperatures caused this form to aestivate. On the other hand, this species may have been more active at night, as was true of some of the larger snakes. As we were not equipped to carry on night collecting any statement is mere conjecture.

36. *Opheodrys aestivus* (Linné)

Examples of the rough green snake were taken from four localities as follows: LeFlore County: 5.2 miles north of Stapp, 1.5 miles northeast of Zoe, six miles southeast of Page. McCurtain County: a single specimen from

two miles southwest of Smithville. Generally the rough green snake is very common, but they were few in number during 1934. Those which were taken were found crawling through the bushes in moist situations.

37. *Coluber constrictor flaviventris* (Say)

A large number of these snakes were taken from all camps. Without doubt, the racer is the most versatile terrestrial snake in eastern Oklahoma. We found it abundant along fence rows, climbing in bushes and small trees, in dry pine-oak forest, and in bottomland forest. From the standpoint of numbers it is apparently the most common of the land snakes. However, it may well be that this species is more resistant to drought conditions. Three specimens, two males and one female, were taken June 17, at the foot of Black Fork Mountain, five miles east of Page. When first seen these snakes were very close to one another. It may be that the breeding season is indicated by this aggregation, as in all other cases the individuals were found singly.

It is of note that in southeastern Oklahoma the racer has the coloration of Florida specimens as described by Ortenburger (1928a) in his monograph on the whip snakes and racers. In central Oklahoma the common name "Blue-racer" is well applied because specimens from Cleveland, Oklahoma, McClain and Payne Counties are all greenish-blue above with yellowish underparts. Those taken during 1934 were all blue-black above, with underparts and throat whitish. They also seem to be longer and slimmer snakes.

Specimens were taken at all hours of the day but the greatest number was taken in the morning, up to nine or ten o'clock. After this time they were rarely moving but late in the afternoon they again became active. This statement is generally true for all terrestrial snakes taken in any numbers.

38. *Masticophis flagellum flagellum* (Shaw)

The whip snake was fairly common in LeFlore and McCurtain Counties, although no specimens were taken at Camp IV. It was taken from all other camps. One specimen was taken June 6, while it was crossing the highway four miles east of Stuart, Pittsburg County. This species is somewhat like the blue racer in habits but it is seldom found climbing among bushes. It was taken most often along fence rows, although specimens were obtained from Black Fork Mountain, and from pine-oak forest.

39. *Elaphe obsoleta obsoleta* (Say)

Several examples of the pilot black snake were taken at Camps I, II, III, and IV. They were sometimes found climbing small trees or among bushes. along fence rows, and in typical bottom land forest.

40. *Elaphe obsoleta confinis* (Baird and Girard)

This subspecies was obtained only at Camps I and IV. Two specimens taken 6.5 miles west of Heavener were in weeds and brush where it was rather damp. Another specimen taken 13.5 miles southeast of Broken Bow about nine o'clock in the morning was swimming in a small, cold, spring-fed pool. A bat, *Nycticeius humeralis* (Raf.) was taken from its stomach. Digestion had scarcely set in.

It appears from the data that *E. o. confinis* has a finer sense of habitat selection, seeming to prefer damper situations, and being less often found climbing among bushes or trees than is *E. o. obsoleta*. While the two subspecies occupy the same area, *E. o. obsoleta* is about five or six times more numerous than *E. o. confinis*. This ratio may have been influenced by the unusual conditions, for, if the latter subspecies prefers more moist situations as is indicated, it would probably tend to be affected more seriously by drought conditions. On the other hand, competition between subspecies may have a bearing on the ratio given. An equal amount of collecting in the same area during a more nearly normal year might help clear up this point.

41. *Lampropeltis calligaster* (Harlan)

Only a single specimen of this king snake was taken. The individual in question was crawling through heavy grass bordering a cultivated field, six miles west of Heavener. This species is widely distributed throughout Oklahoma and is generally one of the most common king snakes of any locality.

42. *Lampropeltis getulus holbrooki* (Stejneger)

Two specimens of the yellow-speckled king snake were taken, one on Rich Mountain, five miles west of Page, and the other from a dry, abandoned well about three miles south of Smithville. The latter was associated with eight toads *(B. a. americanus)* and one copperhead. Another individual was seen crawling into a hole six miles west of Heavener.

According to the residents, both of these king snakes are normally very common throughout the two counties. The few specimens taken certainly indicate an unusual scarcity, perhaps due to the season.

43. *Natrix rhombifera* (Hallowell)

But a single specimen of this large, ill-tempered *Natrix* was taken. It was found swimming in a shallow, roadside pool, about three miles east of Summerfield, LeFlore County, June 7. Ortenburger (1927) reported this species from McCurtain County. Apparently it is an uncommon species in the counties studied.

44. *Natrix sipedon sipedon* (Linné)

A large number of specimens of this species was taken. It was common in every locality where we collected.

45. *Natrix sipedon transversa* (Hallowell)

Like the preceding, this form was very common. We obtained it at Camps II, IIa, III and IV. It seemed to occur in nearly every stream and was associated with *N. s. sipedon*. Often, both subspecies would be taken within a few feet of one another.

46. *Natrix fasciata confluens* Blanchard

This handsome snake was taken only in southeastern McCurtain County in the area immediately adjacent to Camp IV. It was abundant and most often found beneath the debris of drift piles, under logs or along the margins of the sloughs. It must reach the northern limits of its range within a few

miles north of Camp IV as we did not take it at Camp III, or near the Narrows, ten miles south of Camp III.

47. *Storeria dekayi* (Holbrook)

Three specimens of DeKay's snake were obtained. One of these was found in the deciduous forest 1.5 miles northeast of Zoe and the other two were taken from a drift pile 12 miles southeast of Broken Bow.

48. *Thamnophis sauritus proximus* (Say)

A single specimen of this species was taken from among the bushes bordering the headwaters of Shawnee Creek, five miles southwest of Page, LeFlore County, and two others were taken on Rich Mountain in the same general locality. A series of this form was obtained from the vicinity of Camp IV. Here they were common under logs along the dried stream courses and among the vegetation of the bottomlands. One specimen, taken from a mouse nest in a log beside Mountain Fork had eaten two large leopard frogs *(R. sphenocephala)*. Another individual taken from under a log had a single frog of this species in its stomach.

49. *Thamnophis sirtalis sirtalis* (Linné)

Only six examples of this ribbon snake were taken during the summer. Spot records are: LeFlore County: six miles west of Heavener, 1.5 miles east of Zoe; McCurtain County: 16 miles southeast of Broken Bow. They occupied the same type of habitats as *T. s. proximus*.

Garter snakes were not so abundant as one would expect. The specimens which were taken were in in more or less moist situations. It is probable that the high temperatures and lack of rain influenced their numbers considerably. Of the two species taken *T. s. proximus* was more than twice as common as *T. s. sirtalis*. Fourteen examples of the former and six examples of the latter were taken.

50. *Tantilla gracilis* Baird and Girard*

Ortenburger (1927) reported this species from McCurtain County and Burt (1935) obtained specimens from two miles southwest of Heavener, LeFlore County.

51. *Agkistrodon mokasen mokasen* Beauvois

The typical subspecies has been shown by Gloyd and Conant (1934) to occupy eastern Oklahoma. One specimen was taken two miles northeast of Zoe, at the edge of a cotton field just before dark. Another taken after dark two miles southwest of Smithville buzzed his tail viciously and struck at random several times. Three others were taken from old, dry, abandoned wells two miles south of Smithville. According to residents of the country, the copperhead is rather common during ordinary years and is often killed. It has decreased greatly in numbers during the last decade due to the influence of man. The few specimens we took indicate that perhaps the copperhead was moving freely at night.

52. *Agkistrodon piscivorous* (Lacepede)

Cottonmouths were very common and were taken at all camps. Only one or two specimens were taken in the vicinity of Camps I and II, but this is probably due to the large numbers of fishermen, vacationeers, etc., who kill all snakes at sight. These snakes were generally found under flat stones or logs, in brush piles, drift piles and the like. A single specimen was taken about ten miles southeast of Broken Bow in pine-oak forest. There was no water of any kind within at least a mile of the spot where this specimen was taken.

Like *Natrix*, the cottonmouths are great fish eaters. A specimen taken 1.5 miles north of Zoe had several sun perch *(Apomotis cyanellus)* in its stomach. Another taken southeast of Broken Bow had eaten six catfish *(Ameiurus)* six to ten inches long. A large specimen taken 15 miles southeast of Broken Bow had swallowed a water snake *(Natrix s. transversa)* about 18 inches long. Others had been eating frogs, mostly *Rana sphenocephala.*

53. *Crotalus atrox atrox* (Baird and Girard)

Only two specimens of the diamonded back rattler were obtained, both from the vicinity of Zoe. One had been badly mangled with an axe and the other had been shot in numerous places. It is apparent that individuals of this species are rather scattered and few in number in the area studied. Farmers and lumbermen will probably reduce this species so that it will be hard to find in another few years.

54. *Crotalus horridus* Linné

The timber rattler is still rather common in LeFlore County, particularly in the unsettled, wilder localities. Several specimens were obtained six miles west of Page on Rich Mountain. Mr. Vinson brought in two specimens obtained in huckleberry patches far up on the side of the mountain and during the stay at Camp IIa two others were taken from around springs. One large specimen was taken from the dry rocks of the stream bed at the headwaters of Shawnee Creek about nine o'clock one morning. By this time the sun was high and it was rather hot. This snake was sluggish and offered little resistance to capture. Another specimen was taken in high grass along the road near Camp II. Mr. Vinson told us that many of these snakes are seen during more normal years.

In McCurtain County the lumbermen told us that it was common when there was more moisture.

Turtles

55. *Sternotherus carinatus* (Gray)

Several specimens of this turtle were taken from Mountain Fork River at both Camps III and IV. Most of them were caught in a small hoop net. They were very common.

56. *Sternotherus odoratus* (Latreille)*

This turtle has been reported from McCurtain County by Ortenburger (1927) and from two miles southwest of Heavener, LeFlore County by Burt (1935).

57. *Macrochelys temminckii* (Troost)

A large carapace of this species was found in Mountain Fork River at Camp IV. The large size, general shape, three prominent dorsal keels and other characters make the identification certain. Residents of the area along the river told us that large turtles, weighing as much as 50-60 pounds are occasionally taken. It is probable that they are of this species.

58. *Chelydra serpentina* (Linné)

The snapper is commonly found in the streams and pools throughout the area studied. Specimens were secured at all camps.

59. *Terrapene ornata* (Agassiz)*

Ortenburger (1927) recorded this species from LeFlore County. It is apparently very rare throughout southeastern Oklahoma.

60. *Terrapene triungis* (Agassiz)

This species was commonly found in the neighborhood of Camps I, II, and III. It was taken most often in forested areas. Three specimens which were grouped about a rotten log eating white grubs were taken six miles west of Heavener on the bank of Conser Creek.

61. *Graptemys pseudogeographica pseudogeographica* (Gray)

This handsome turtle is common in the areas studied. It was taken from Camps I, II and III, and seen at Camp IV.

62. *Graptemys pseudogeographica kohnii* (Baur)*

Ortenburger (1927) recorded this subspecies from both LeFlore and McCurtain Counties.

63. *Pseudemys elegans* (Wied)*

This species is recorded from McCurtain County by Ortenburger (1927) and from LeFlore Couunty by Burt (1935).

64. *Pseudemys texana* Baur

Many specimens of this turtle were taken in the neighborhood of Camps I, II, III, and IV. It appeared to be the most abundant turtle in the areas studied.

65. *Deirochelys reticularia* (Latreille)*

This species was reported from McCurtain County by Ortenburger (1927).

66. *Amyda emoryi* (Agassiz)*

Reported from LeFlore County by Ortenburger (1927).

67. *Amyda ferox* (Schneider)*

Recorded from LeFlore County by Ortenburger (1929).

68. *Amyda mutica* (LeSueur)*

Reported from McCurtain County by Ortenburger (1927).

69 *Amyda spinifera* (Le Sueur)

This soft shell turtle is common in all of the larger streams of the areas studied, and specimens were either taken or seen in the neighborhood of all camps.

Discussion

The effects of the unusual climatic conditions upon the amphibian and reptilian population may conveniently be discussed under two heads—first, the effect upon the aquatic species, and secondly, the effects upon the terrestrial species. In the first case the evidence is direct and positive. In the second it is indirect and mostly negative.

Effect upon Aquatic Species

The water snakes as a group showed a direct response to the drying up of the smaller streams. As the water became more and more restricted to small holes the aquatic snakes and fish became concentrated at these points. During the three days spent at Camp IIa, 15 *Natrix* and 14 cottonmouths were taken from water holes along a half mile stretch of a small stream. On June 28 and 29, 16 *Natrix* and nine cottonmouths were taken from under stones and small pools in the nearly dry stream bed at the headwaters of Shawnee Creek. During the stay at Camp III, ten cottonmouths were taken from a small tributary of Mountain Fork which was about one-quarter mile long. Seven of these were taken in a single day. Along a small tributary of Mountain Fork, 12 miles southeast of Broken Bow, ten *Natrix* and 17 cottonmouths were taken in three days. Most of them were in drift piles, under logs, etc.

Most of the water snakes had been preying on fish and the number eaten must have run into the thousands. The effect of a concentrated reptile population upon the habitat must be serious during drought years when the water of the smaller streams becomes restricted to occasional pools.

The large numbers of *Natrix* and cottonmouths along the smaller water courses may be attributed to two factors. First, as the streams become more and more restricted to pools, the snakes necessarily become concentrated in these pools. This is probably the most important factor influencing their numbers under drought conditions. Secondly, it is possible that the water snakes migrated from the larger streams, such as Black Fork and Mountain Fork, to the pools of the smaller streams where the fish were concentrated and the hunting better. The evidence for this is not conclusive, but very few *Natrix* or cottonmouths were taken along the larger streams.

Only one or two specimens were secured from Freeman Hole of Black Fork and not many more from several other localities along the river. Neither were these forms abundant along Mountain Fork at either Camps III or IV. Of course it is recognized that snakes are not so easily taken from the shores of larger bodies of water, but on the other hand, experienced field collectors will see them if they are present. Furthermore, along the larger streams, the numbers of reptiles is kept down by the never ceasing war against them by fishermen and campers. Despite these objections, the writer is inclined to be-

lieve that there is some migration from larger to smaller streams during drought conditions.

The amphibians were also concentrated in and around the smaller pools. It seems only necessary to point out that six species new to the state were taken to emphasize this point.

Effect upon Terrestrial Species

As indicated above, comparatively few individuals of a majority of the terrestrial species were taken. Any statement regarding the response of these forms to drought conditions must be based, therefore, on inference and on statements made by residents of the country.

In general, land snakes were few in number and were most often found in the neighborhood of water. *Coluber* was an exception to this and numerous individuals were taken. Likewise the lizards, particularly *Sceloporus, Cnemidophorus,* and *Leiolopisma* were abundant. In contrast, few individuals of *Diadophis, Heterodon, Lampropeltis, Opheodrys, Storeria, Thamnophis, Crotalus* and *Agkistrodon m. mokasen,* etc. were taken. This may have been governed by a number of factors.

First, the lack of moisture and the high temperatures may have caused many of them to asetivate. Secondly, members of all of these genera may have been active during the night, as was indicated for *A. m. mokasen.* No night collecting was done and there is no positive evidence to substantiate this statement. However, tracks of large snakes which had been moving during the night were commonly seen in sandy areas and in the loose dust of the country roads. If the snakes were more active at night they must have concealed themselves shortly after daylight for we were generally in the field by six o'clock. It is also possible that there was a real scarcity of terrestrial snakes during 1934. It is a striking fact, however, that such forms as *Heterodon, Lampropeltis, Thamnophis,* etc., were rarely taken, and according to the reports of numerous residents of the area, these forms are generally common. There is little doubt, in the mind of the writer, but that these forms were less often taken due to drought conditions.

Few individuals of the several species of the genus *Eumeces* were taken. It seems likely that their numbers were also influenced by the severe dryness. In Cleveland County, the writer has found eggs of several species of the genus during June, July and August of other years. It is a significant fact that we found no lizard or snake eggs during the summer of 1934. It is probable that the breeding season was delayed by unfavorable climatic conditions.

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Notes and Discussion

MUSTELA CICOGNANII, THE SHORT TAILED WEASEL, INCORRECTLY ASCRIBED TO OHIO

E. Raymond Hall

An erroneous identification of an animal or plant which furnishes a marginal locality of occurrence, if uncorrected at the first opportunity has a way of being repeated in the literature until it causes no end of mischief. The late Reverend W. F. Henninger's[1] recording of a male *Mustela cicognanii* from New Bremen, Ohio, as a first record of the species for the state and the subsequent mention of this far southern occurrence by Seton,[2] Hamilton[3] and Lyon,[4] each author probably feeling more secure than the one before because of the increased weight of authority attached to the record, is a case in point. The specimen, no. 925 in the collection of the Ohio State Museum at Columbus, kindly loaned to me by Mr. Edward S. Thomas, proves upon examination to be a female long-tailed weasel, *Mustela frenata noveboracensis* (Emmons); of common occurrence throughout the state.

Reverend Henninger was not unique in his misidentification for many naturalists have confused the female long-tailed weasel with other species. Audubon and Bachman[5] even went so far as to propose the new name *Putorius agilis* for the female of *Putorius noveboracensis*, believing it to be a species distinct from the male. However, the collector's measurements (268-67-30) of the Ohioan specimen are subject to correction. The hind foot in the dry state measures 32.2 millimeters. The part of the tail bearing the black pencil is gone and microscopic examination shows that the end of the tail had healed over before the animal's death. With the complete tail, and allowing for the shrinkage of the hind foot in drying, the external measurements would be about 293, 92, 33, or as in other females of *M. f. noveboracensis* and intermediate in size between male and female *Mustela cicognanii* to the north of Ohio. Size of the skull over all, length of the tooth-row, and configuration of the tympanic bullae are similarly intermediate and agree with the corresponding parts in females of *M. f. noveboracensis*.

That the specimen is a *Mustela frenata noveboracensis* clearly is shown by the well developed postorbital processes of the frontal bones, brown, rather than white, lips, feet and ankles, and restriction of the light color of the underparts.—MUSEUM OF VERTEBRATE ZOOLOGY, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIFORNIA. December 9 1936.

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1 Journ. Mamm. **2**:239, 1921.
2 Lives of Game Animals **2**:585, 1929.
3 Present Journal **14**:290, 1933.
4 Present Journal **17**:109, 1936.
5 Quadrupeds of North America, p. 184. 1854.

Book Reviews

DOWN TO EARTH, by Carey Croneis and William C. Krumbein. Chicago: University of Chicago Press, 1936. xviii + 501 pp. $3.75.

The authors of this "new plan" text affirm their belief in Lyell's dictum that the scientist must write what will be read. The readers of an elementary textbook are not scientists. The authors therefore have striven to produce a book novel in style, attractive in appearance, and pleasantly readable.

This does not mean that they have reduced or diluted. Their 45 chapters deal with most of the subjects treated by "standard" textbooks of physical and historical geology, plus a few generally absent from them. The book seems much too long for a semester course, and perhaps is so for a year course meeting but two or three hours per week. It contains material more difficult of comprehension than that in texts by Norton, Branson and Tarr, Miller, and Scott—though Scott's *Introduction to Geology* is far from a superficial book. Chapters on physical implications of geology, seismology and correlation based upon phylogenies are examples of difficult subjects handled without concession to indifference of students.

The style of writing is fluent, readable and more dramatic than that of the usual textbook. Table of contents and chapter headings suggest a somewhat labored effort for flashiness in phrasing but the text does not bear them out. Emphasis has been secured without loss of coherence and unity; novelty is achieved without the confusing figures of speech and the lack of definiteness which mar such purely popular books as Bradley's *Autobiography of the Earth*. Readers of Croneis and Krumbein will not find themselves wondering what, precisely, the authors said — only to find that they have said nothing precisely.

It is in illustrations that the book departs most radically from "standard" texts. Most of the photographs have been assembled into sixteen-page rotogravure signatures, each furnishing a synopsis of several chapters. These rotogravure plates are most successful in such fields as petrology and mineralogy; least successful in vertebrate paleontology. In some, the individual figures are too small to be useful; in others, they would have profited by retouching, or show that copy was made too large for the final plate.

The text is illustrated chiefly by zinc etchings which range from reproductions of engravings in the Nuremberg Chronicle of 1493 to humorous sketches by Chichi Lasley, and portraits of geologists by Raymond Hirsch. Some of the last are downright poor drawing, the sketches of Agassiz, Lyell and Logan being specially bad. The full-page restoration of La Brea pits on page 455 is good enough as a thumbnail sketch but too crude anatomically to be worth while, as are the pictures of elephants on page 453. Cuts from old engravings are interesting historically, but their value in an elementary book is doubtful. Unless accompanied by helpful comments from the teacher, they may inspire ridicule rather than understanding by students, thus partly defeating the authors' intentions in selecting them.

Finally, *Down to Earth* does little toward solving one of the most vital problems of geologic instruction: that of relating geology as a science to geology as scenery, and as material for recreation. Whether intentionally or not, the authors proceed on the familiar assumption that any student *may* become a geologist, rather than on the fact that most students will not be geologists and must have their mature contacts with that science through the medium of motor tours and other recreational activities. While *Down to Earth* may do better than most elementary textbooks, it still leaves geology primarily a matter of classroom and laboratory, not of the earth over which students and ex-students travel in ever-increasing numbers. — C. L. FENTON.

FLORIDA SEA SHELLS, by Bertha D. E. Aldrich and Ethel Snyder. Boston and New York: Houghton, Mifflin Co. 126 pp., 11 plates. $1.25.

A concise manual for identification of common molluscs, coelenterates, echinoderms and a few other organisms of Florida, prefaced by a general description of Florida beaches and a short history of human attention to molluscs. A chapter is given to each molluscan class, with a comprehensive survey of morphology preceding descriptions. Non-technical throughout, the book is best adapted to use by those untrained in conchology — whether layman or scientist makes no great difference. There are bibliographies, two indices and good photographic plates, some of which, however, have been trimmed too closely. — C. L. FENTON.

HERPETOLOGICA. A journal devoted to the study of Reptiles and Amphibians. Edited by Chapman Grant and Walter L. Necker. Published at the Chicago Academy of Sciences. Subscription $1.00 the volume. Vol. I, No. 1. July 11, 1936.

The first third of our century has seen a rise of interest in and enthusiasm for the study of amphibians and reptiles, for which the somewhat vague term "Herpetology" is still in vogue. In North America, especially, a whole school of herpetologists, with varied interests, has developed. The reasons for this renaissance of herpetology are several. On one hand, these two classes of vertebrates had been relatively the least studied as to taxonomy, anatomy, and ecology. In another direction, amphibians had become of extreme importance in the development of experimental embryology, and physiology. The steady progress of paleontological studies has produced astonishing results, and has had a strong reaction stimulating anatomical studies of the living forms. By no means the least factor in the movement was the presence in the principal museums and in a few universities of strong personalities who were interested in this field, and who promoted or gave direction to the studies of their younger associates.

The appearance of the new journal *Herpetologica* is a significant event in this widespread movement. The senior editor, Major Chapman Grant, of San Diego, is known to herpetologists especially for his brilliant field work in Puerto Rico. The junior editor, Mr. Walter L. Necker, of the staff of the Chicago Academy of Sciences, is especially well known to this reviewer, since his herpetological and bibliographic interests have developed in part in the laboratories of the Field Museum.

The first paper is appropriately a tribute to Mrs. Helen Thompson Gaige, editor for herpetology of the journal *Copeia*. With this is included a bibliography of her published papers. Considering the difficulty of obtaining complete lists of the papers even of living authors, it is to be hoped that such lists may be made a continued feature of *Herpetologica*. The papers presented in this first number include a variety of topics, ranging from locality records in the United States to descriptions of new species from Mexico and Brazil. The extraordinary pattern dimorphism of the California king snake is set forth by L. M. Klauber. An essay on the nomenclature of myology by D. Dwight Davis, describes the confusion in this field, with some suggestions for future procedure. The fixation of the type locality of the common leopard frog, *Rana pipiens*, as New York, rather than New Jersey, is suggested by Carl F. Kauffeld; it is to be hoped that this may be valid, for it will avoid the transfer of whole pages of synonymy, and volumes of experimental work, to another name.

Theeditors are to be congratulated on their effort to provide this additional outlet for herpetological papers, at a moderate cost. A table of contents and index is to be provided for the volumes as they are completed.—KARL P. SCHMIDT, Field Museum of Natural History.

295 AMERICAN BIRDS. Color Plates from Bird Portraits in Color, by Thomas S. Roberts. Minneapolis: University of Minnesota Press, 1936. 90 plates and index. $2.00.

This is a second republication of the plates in Dr. Roberts' *Birds of Minnesota*, this time without text. The binding is spiral, permitting the book to open flat or fold back. There has been no loss in quality of printing, and the plates make a useful supplement to such books as Chapman, or to state lists. With the plates comes information that a new printing of Dr. Roberts' complete work will be made soon. It will be welcomed by those who neglected to secure copies of the first printing.—C. L. FENTON.

OCTOBER FARM, from the Concord Journals and Diaries of William Brewster, with an introduction by Daniel Chester French and a foreword by T. Barbour. Edited by Rev. Smith Owen Dexter. Cambridge, Mass., Harvard University Press, 1936. Pages i-xv and 1-285. Five unnumbered plates, [of the farm and surrounding country]. Price $2.50.

This is a collection of excerpts from Brewster's diaries from the time he was twenty-one until shortly before his death at the age of sixty-eight. Probably the diaries were not written for publication, but, the excerpts as issued, form a delightful collection of short essays about nature as observed by Brewster in the vicinity of Concord, Mass. One would expect diaries of Brewster, the distinguished ornithologist to be restricted to the subject of birds, but they contain observations on at least 17 species of mammals as well as on turtles, snakes and lower forms of life. He also mentions the many guests interested in nature who visited him at October Farm.

His descriptions of the habits of the various animals mentioned are given with great detail, and one marvels at his restraint in not interfering with the events of nature, an example well worth emulating by others in public as well as private life. He has many notes on the plant life including descriptions of the woods of his estate, especially the aquatic plants for which there was ample habitat. He had numerous boats and canoes available for himself and friends, and cabins in which to spend the night away from the farm house proper. His estate comprised about 300 acres.

There seems to be almost no change in his pleasing style from the time of his first entry to the last. When one realizes what a small portion of his diaries is compressed into 285 pages, it seems unfortunate that not more of them is available to those who are interested. The value of the book would be enhanced by an index of the animals and plants described, as well as of the persons who visited October Farm.—M. W. LYON, JR.

THE MAMMALS AND LIFE ZONES OF OREGON, by Vernon Bailey. North American Fauna No. 55. U. S. Dept. of Agriculture, Bureau of Biological Survey. Washington, D. C., June 1936. 416 pp., 52 pls., 102 figs., 1 colored map. $0.75.

"The Mammals and Life Zones of Oregon" is the latest addition to the long list of North American Faunas. It is a splendid contribution from the pen of that indefatigable and veteran naturalist, Vernon Bailey. The first 56 pp. are devoted to an excellent account of the life zones and physiography of the state. The remaining 350 pp. are devoted to an annotated list of the species occurring in the state together with a bibliography. There are 102 text figures illustrating the geographic distribution of most of the species, and 52 well chosen plates illustrating important mammals, in-

cluding the Whales. No aspect of the mammals of the state seems to have been forgotten. Each species is designated by the accepted scientific name as well as the common English name, and frequently also the name employed by the Indians. In addition to the technical descriptions are accounts of distribution and habitat, general habits, breeding habits, food habits, and economic status. The author, by long training and experience, is well qualified to prepare such a work. In the front is a colored map of the state showing the life zones.—M. W. LYON, JR.

THE MUSHROOM HANDBOOK, by Louis C. C. Krieger. Macmillan, New York, 1936. 512 pp., 126 figs., 32 col. pls. $3.50.

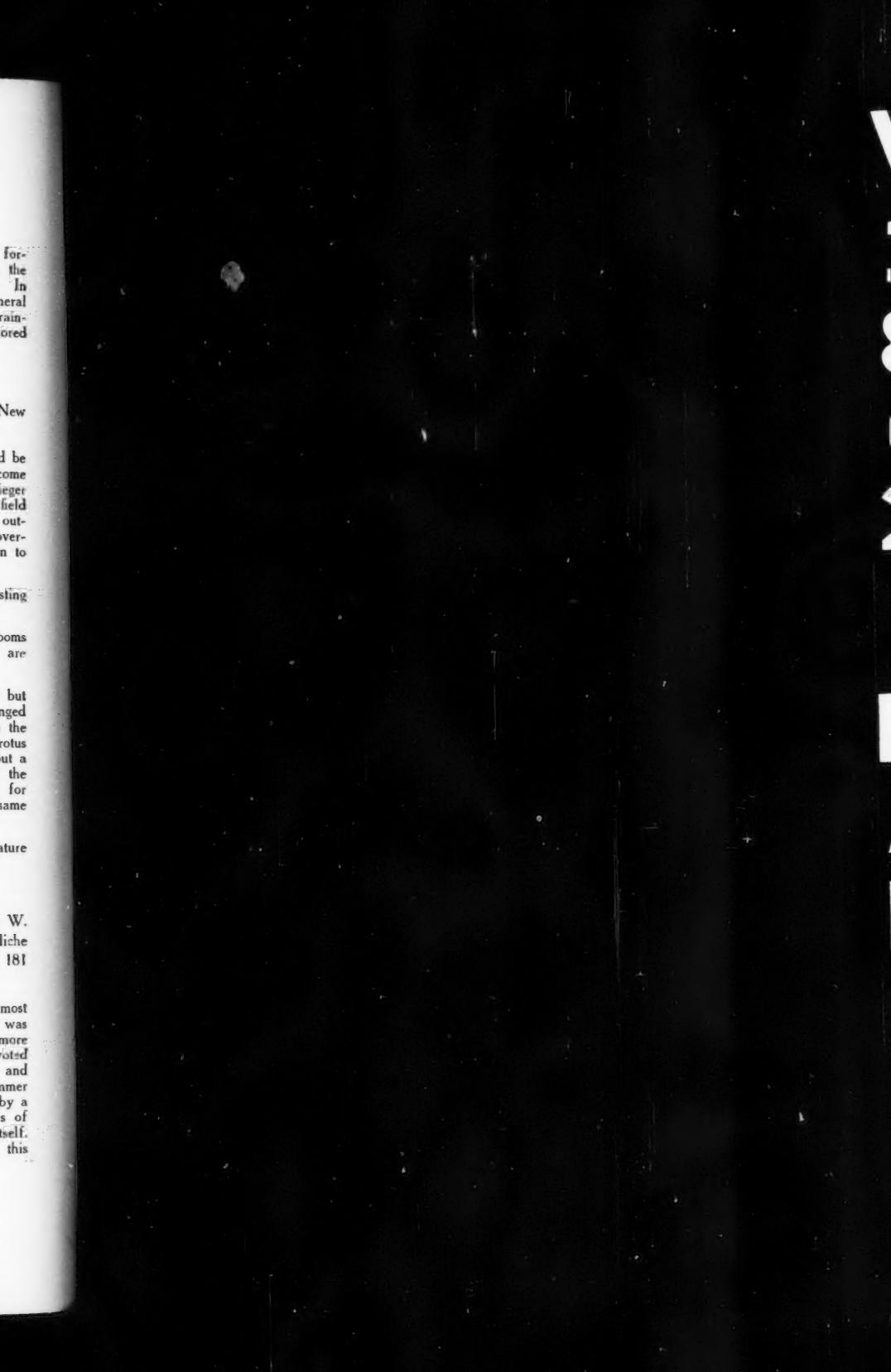
The advent of a new book on mushrooms, particularly a popular guide, should be welcomed by all who are interested in this peculiar group of plants. This welcome should be especially enthusiastic when an artist of the attainments of Mr. Krieger makes available to the public the results of his many years of observation in a field in which he has made his most intensive study. In the Mushroom Handbook the outstanding quality of the colored illustrations and the line drawings of the author overshadow the text. As might be expected the half-tones are also excellently chosen to illustrate the species they represent.

The text is informally but informingly written and contains a wealth of interesting facts arranged in such a manner as to be entertaining as well as instructive.

In addition to an extended discussion of the "conditions under which mushrooms grow and thrive," the chapters on "mushroom growing" and the "bibliography" are worthy of special mention.

The keys and descriptions are chiefly compiled from earlier standard works, but have been carefully selected to meet the author's needs. The descriptions are arranged alphabetically by genera with the species alphabetically within the genus. While the species descriptions are easy to find, the sandwiching of Polyporus between Pleurotus and Psalliota, for example, seems a bit incongruous to the student who has any but a very superficial knowledge of the fungi. Since in the keys the arrangement of the species into genera and families is followed, it would seem that the advantage for comparative purposes of keeping related forms together would have made the same arrangement preferable.

All in all, the volume is a very acceptable addition to the popular literature concerning the fungi.—J. C. GILMAN.

MUTATIONSFORSCHUNG IN DER VERERBUNGSLEHRE, von N. W. Timoféeff-Ressovsky. Wissenschaftliche Forschungsberichte, Naturwissenschaftliche Reihe Band 42. Verlag von Theodor Steinkopff, Dresden und Leipzig. 1937. 181 pp., 6 pls., 52 figs., 49 tables. RM 16,50.

The great importance of the scientific study of mutations has been apparent almost since DeVries first described them under this term. Yet an entirely new angle was obtained when radiation was applied in the artificial production of mutations, or more specifically so, since Muller's classic experiments of 1927. The present treatise devoted wholly to this special phase of genetics presents in convenient form an admirable and up-to-date summary. The author's researches in this field led him with others (Zimmer and Delbrück) to propose the so-called "Treffertheorie" (the probability of a hit by a photon [light quantum]) in an effort to advance the knowledge of the processes of mutation and hence proceed to a better understanding of the nature of the gene itself. Not only geneticists but biologists in general will be obliged to the author for this highly reliable and timely book.—TH. JUST.